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UPON THE CONSTRUCTION OF THE WHEATSTONE BRIDGE FOR ELECTRICAL RESISTANCE THERMOMETER.

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THE electrical resistance thermometer is now widely recognized as one of the most available and best of the many devices that may be employed as an accurate secondary standard for the measurement of temperature, and methods for its easy manufacture are greatly to be desired.

The present ultimate standard scale of temperature is Lord Kelvin's so-called thermodynamic scale, or the almost identical scale of the constant volume hydrogen thermometer. It is well understood that other scales, such as one obtained from the expansion of mercury-in-glass, or from the temperature variation in resistance of some metal, or from the potential change in some thermo-junction, or from any other temperature effect, all differ from each other and from the standard scale. Whenever, therefore, any one of the secondary thermometers is employed, its readings must generally be reduced to the gas scale of temperature by some more or less elaborate conversion tables or sets of corrections. The question of the interrelation of different thermometric scales is a very extensive one, and we point out here simply the essential fact that they are all different.

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The purpose of the present paper is to describe definite and exact methods by which manufacturers of electrical instruments can construct resistance thermometers so as to indicate temperatures on the gas scale directly and thus avoid the necessity of the troublesome conversion tables commonly employed.

Resistance thermometers can already be obtained, provided with direct reading temperature scales, but these are produced by a sort of cut and try process that is not only tedious in its application, but the results are not so certain or so uniformly exact as those obtained by the method we wish to describe.

The change in resistance of electrical conductors with temperature is rarely or never exactly proportional to the change in temperature. It is therefore generally necessary that the scale on the instrument from which the true temperature is to be read, must be one of unequal parts, or the steps in resistance corresponding to the intervals on the scale must be unequal. In the instruments heretofore made it is often customary to resort to both these expedients in order that readings shall be expressed directly in standard temperatures; that is, the subdivisions of the scale are made unequal and the steps in resistance corresponding to successive intervals on the scale are also made unequal. Now it is a very easy matter to subdivide a scale into a given number of sensibly equal parts, but it is a very difficult or nearly impossible thing to subdivide a scale into progressively unequal parts that shall correspond accurately to some complex law of inequality. So, likewise, it is a very easy thing to make up numerous steps or intervals of resistance all sensibly equal to each other, but progressively unequal steps in resistance can be produced only by the expenditure of time and tedious hand work.

The methods of construction herein described enable one to make up a resistance thermometer in which the subdivisions of the scale are equal and so also are the steps of the variable resistance, nevertheless the readings are in standard temperature units subject only to certain very small errors that in general are even smaller than the customary unavoidable errors of manufacture. The studies thus far have been restricted chiefly to ordinary atmospheric ranges of temperature, say from — 40 to + 60° C. The mathematical relations, however, are general and admit of application to widely different conditions.

The order of accuracy aimed at may be put at, say, about one-tenth of a degree; that is, discrepancies of this amount may be tolerated. The method, therefore, can be employed in the construction of a large class of thermometers, such, for example, as are used in meteorological observations, in many manufacturing processes, and for commercial purposes generally where moderate ranges of temperature at approximately atmospheric conditions suffice.

In the new construction we simply avail ourselves of certain interesting mathematical relations between the equations representing the changes of resistance of the given thermometer with temperature and the equations for the bridge, according to the particular arrangement of resistances employed.

The close mathematical similarity between the equations referred to was pointed out for a particular case in a previous paper.[1] More exact data than was originally available have recently been obtained relative to the variation of the resistance of nickel over ordinary atmospheric conditions of temperature, and, in the present paper, we shall develop the mathematical relations referred to more fully and extend their application to the general problem of constructing bridges and indicating devices to give gas scale temperatures directly by means of resistance thermometers made of various kinds of material.

The relation between the temperature and resistance of nickel, of the quality ordinarily supplied by the customary dealers in the form of wires, can be quite accurately represented over a range of temperature, say, from -40 to $+70°$ C. by a logarithmic equation of this form:

$$Log.\ R = a + bt - ct^2 \qquad (1)$$

The term in t^2 is wanting, that is c is zero for some specimens of nickel, but in most cases, as shown by the wires thus far examined, the t^2 term must be retained, although the value of c is very small; that is, for the range of temperature considered, the temperature resistance curve can be represented with sufficient exactness by a logarithmic equation of the second degree.

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[1] Note on the relation between the temperature and resistance of nickel. C. F. Marvin, Phys. Rev., vol. xxx, No. 4, Apr. 10, 1910, pp. 523–528.

Table I gives equations for several specimens of nickel wire and ribbons, and also for the purposes of comparison the equation of one of the platinum thermometers, No. 478, used by Messrs. Waidner and Burgess [2] at the Bureau of Standards in studies of platinum thermometry.

In each of the thermometers, Nos. 39 to 52, a small length of manganin wire was joined in series with the nickel, in order to slightly lower the temperature coefficient and thereby be able to reproduce it at any future time by the use of wire from new

TABLE I.

EQUATIONS FOR NICKEL RESISTANCE THERMOMETERS FROM DIFFERENT STOCK, AND FOR PLATINUM THERMOMETER B.S. No. 478; TEMPERATURE RANGE FROM $-40°$ TO $+60°$ C.

Equation for Nickel:—$Log.\ R = a + bt - ct^2$
Equation for Platinum:—$R = a + bt - ct^2$

Thermometer number	R at 0° observed	a	bt	ct^2
	ohms.			
Spiral I	10.668	1.02806	.00211t	.000000720t^2
Spiral II	2.139	0.32818	.00206t	.000002209t^2
Spiral IIa	2.538	0.40449	.00214$0t$	.000002820t^2
Spiral III	12.506	1.09712	.00217$6t$	.000002854t^2
Conical receiver	26.171	1.41782	.00187$9t$	.000002097t^2
Silver block receiver	31.073	1.49238	.00187$6t$	.000001759t^2
Therm. No. 39	93.190	1.96938	.00154$2t$	.000001112t^2
Therm. No. 41	93.334	1.97004	.00151$6t$	.000001016t^2
Therm. No. 43	93.156	1.96925	.00153$8t$	.000001063t^2
Therm. No. 51	93.223	1.96952	.00151$7t$	.000000980t^2
Therm. No. 52	93.184	1.96930	.00153$4t$	.000001013t^2
Pt. therm., B. S. No. 478	5.15665	5.15665	.02027$55t$	.000003010t^2

Spiral III, Quadratic equation, $R = 12.506 + 0.062521t + 0.000069586t^2$

stock of nickel, which might alone have a lower or higher coefficient than the old stock.

Table II gives the difference, observed minus computed resistance, obtained by the use of the equations given in Table I. To simplify the tabulation a small correction has been applied to each observed value if necessary, in order to bring the temperature to the nearest whole degree and thus avoid the presence of small fractions of degrees.

Over the range of temperature considered, it follows from the data that the curve representing the change of resistance of nickel with temperature is *concave* upward. The curve for pure plati-

[2] Bulletin of the Bureau of Standards, vol. vi, No. 2, p. 156, 1910. Reprint No. 124.

num is *convex* upward, and, as is well known, the resistance changes very closely in accordance with the parabolic law over a very great range of temperature, probably from far below zero to 1000° C. more or less. It is immaterial for our present purposes what particular equation is employed to express the temperature resistance data for any particular thermometer.

A careful examination of the data for thermometers No. 39, 41, 43, 51 and 52 shows that, although these instruments are very nearly identical, yet the differences between them, both in the absolute resistance at zero and the law of change, are greater than seem necessary. The difference in the resistances at zero

TABLE II.

COMPARISON OF OBSERVED MINUS COMPUTED RESISTANCE OF NICKEL THERMOMETERS MADE FROM DIFFERENT STOCK; DEVIATIONS EXPRESSED IN TEMPERATURE.

Temp., °C.	Ribbon spirals				Conical rec.	Silver block	Similar therms.				
	I	II	IIa	III			No. 39	No. 41	No. 43	No. 51	No. 52
−36							+.03	−.03	−.02	−.04	−.03
−26			−.01	−.04	+.03	±.00	−.01	+.01	±.00	+.01	+.01
−18			−.02	−.00	+.01	+.02	±.00	±.00	±.00	±.00	±.00
−10			−.04	−.02	−.04	−.02	−.05	±.00	±.00	+.01	±.00
0	±.00	−.01	±.00	±.00	±.00	±.00	±.00	±.00	±.00	±.00	+.01
11	−.02		−.06	−.05	−.05	−.05	−.03	−.06	−.05	−.05	−.03
22							−.02	−.06	−.06	−.08	−.07
33	−.06	−.05	−.25	−.08		−.03	+.05	±.00	−.02	+.03	−.03
45	−.10		+.06	±.00	+.07	+.05					
48	−.08	+.03					+.28	+.15	+.16	+.14	+.14
54	−.02	+.05									
60		−.02	+.35	+.29		+.17					

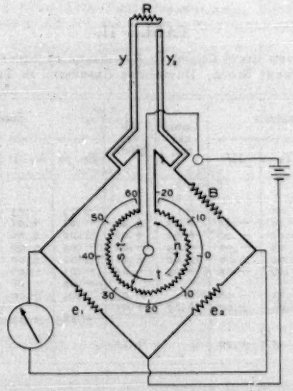
in the extreme is nearly 0.2 per cent., and corresponding differences at other temperatures are apparent. If it is not practicable to duplicate thermometers of a specified type more accurately than shown in these data, then it is impracticable to make thermometers that are strictly interchangeable, or to use a large number of thermometers on one bridge without introducing important errors. Of course corrections for the individual thermometers can be worked out if necessary.

Upon the completion of the numerous observations and mathematical computations required in preparing the data given in Tables I and II, it became apparent that in almost every case the computed value by the logarithmic equation was systematically too high at moderate temperatures, and, especially, was too low

at the highest points observed. This led me to try some other equations on one of the spirals, viz., III, and it was found that the simple parabolic equation $R = a + bt + ct^2$ (see Tables I and II) gave values in still closer agreement with the observations than the logarithmic equation. This form of equation will doubtless be used in future work, but the labor of recomputing all the old observations has not seemed necessary.

We shall pass at this point to the question of the bridge itself, and shall consider the equations and points of advantage of the

FIG. 1.

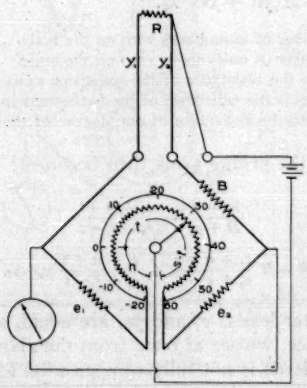


$$\frac{R + 2y_1 + s - t}{B + 2y_2 + n + t} = \frac{e_1}{e_2} \qquad R = B + n - s + 2t, \text{ when } e_1 = e_2 \text{ and } y_1 = y_2$$

several well-known methods of arranging the connections. Four of these are shown diagrammatically in Figs. 1–4, and help to fix the ideas we have indicated a scale of temperature from — 20° to + 60° C. with the thermometer or variable resistance in series with the bridge wire, shown here in circular form with a radial arm carrying the slider. This wire and scale may be made up in a great variety of ways customary to the art in such cases, the only stipulation being that the scale shall be one of sensibly equal parts, and that the portions of the wire comprised between successively equal spaces on the scale shall have sensibly equal

resistances throughout. This arrangement constitutes the customary connections used with the platinum thermometer with dummy leads for compensation; e_1 and e_2 are equal ratio coils, and the equation reduces to the form $R = B + n - s + 2t$. This linear equation gives the so-called platinum scale of temperatures, which requires changing corrections from point to point along the scale to reduce the readings to the gas scale. The four-wire system of compensation leads may sometimes be objectionable as when the thermometers are placed at considerable distances

FIG. 2.



$$\frac{R + y_1}{B + y_2} = \frac{e_1 + n + t}{e_2 + s - t} \qquad R = \frac{A + Mt}{N - t}$$

from the indicator. Other systems of connections are possible, that require only three leads, one of which is simply a battery connection.

In all cases, however, when the platinum thermometer is used on work requiring great precision, the Fig. 1 bridge is doubtless better than any other, in which case the direct temperature scale is dispensed with, and even the slide wire itself is best replaced by some special form of rheostat capable of adjusting the resistance with the required precision.

Fig. 2 represents the resistance thermometer at R joined by

the well-known system of three wire compensation leads, y_1 and y_2 and a battery wire. The balancing coil is at B, and e_1 and e_2, either equal or unequal, are extension coils in series with the bridge wire.

Let R = the resistance of the thermometer in ohms at the nominal temperature t indicated by the bridge scale when the bridge is balanced.
Let $y_1 = y_2 = y$ = the resistance of the lead wires in ohms.
Let B = the resistance of the balancing coil in ohms.

We have assumed for purposes of illustration that the scale extends both above and below zero and comprises a range of temperature from — 20 to + 60° C.

Let n = the number of units below zero on the scale.
Let s = the number of units above zero on the scale.
Let e_1 and e_2 be the resistance of the extension coils. (It is simplest in computations to express the resistance of the extensions in temperature units; that is a unit equal to the resistance of one degree of the bridge wire.)

The ratio of the bridge arms then becomes:

$$\frac{R+y_1}{B+y_2} = \frac{e_1+n+t}{e_2+s-t}$$

$$R = B\,\frac{e_1+n+t}{e_2+s-t} + \frac{e_1+n+t}{e_2+s-t}\,y_2 - y_1.$$

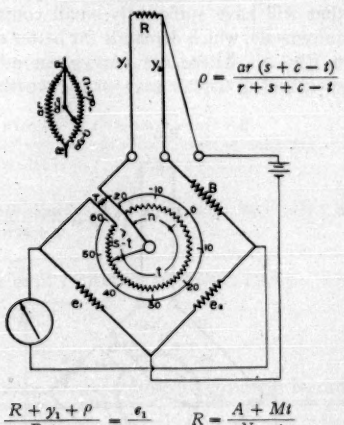
If the thermometer leads, y_1 and y_2, are equal, as is most easily the case in practice, we see at once from the above equation that the effect of the leads is not fully compensated for, except in one or two possible cases. At some particular temperature it may be possible for the coefficient of y_2 to be unity, whence we have perfect compensation for that particular condition only. Or y_1 and y_2 being unequal, we get compensation at some one temperature if y_2 multiplied by its coefficient equals y_1. The compensation is therefore imperfect in this method of wiring, and we shall retain the expression for lead resistances in the bridge equation, which, upon rearranging the terms becomes

$$R = \frac{B\,(e_1+n) - y\,(e_2-e_1+s-n) + (B+2y)\,t}{e_2+s-t}. \qquad (2)$$

This is the general equation of the bridge, and takes into account the resistance of the lead wires, $y_2 = y_1 = y$. But we

have assumed that y is a constant, that is, we neglect, as we may, the small nearly compensated effects due to temperature changes of resistance in the leads. The second member of the equation, therefore, contains only one varible term, namely t. For com-

FIG. 3.



$$\frac{R+y_1+\rho}{B+y_2} = \frac{e_1}{e_2} \qquad R = \frac{A+Mt}{N-t}$$

putation the equation may be reduced to the following simple form:

$$R = \frac{A+Mt}{N-t}. \tag{3}$$

in which,

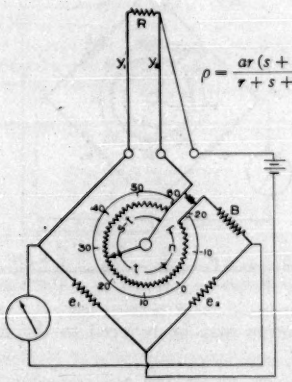
$$\begin{aligned} A &= B(e_1+n) - y(e_2-e_1+s-n) \\ M &= B+2y \\ N &= e_2+s \end{aligned} \tag{3a}$$

Before showing how the general equation may be utilized in designing the bridge, we shall examine the other methods of using the bridge shown in Figs. 3 and 4.

In Fig. 3 the bridge wire is joined in one arm of the bridge in series with the thermometer. The wire is provided with a fixed shunt r, and the slider is joined in as a second shunt, which

in the simplest case may be given a very low resistance. We shall form the equations of the shunt, however, assuming that the slider arm is itself a definite resistance. This will retain the position of this term in the final equation, when the term can be evaluated according to circumstances. In adopting this form of construction it will be necessary to employ some form of wire and slider that will have sufficiently small contact resistance to meet the requirements, which demands far better contacts than are necessary in Fig. 2. There are very great advantages in the case of Figs. 3 and 4, and it may prove worth while to over-

FIG. 4.



$$\frac{R+y_1}{B+\rho+y_2} = \frac{e_1}{e_2} \qquad R = \frac{A+Mt}{N+t}$$

come the obvious difficulties due to contact resistances at the slider. As before, B is the balancing coil and e_1 and e_2 are equal ratio coils of appropriate magnitude.

Following the same notation as before we get

$$R = \frac{e_1}{e_2} B - \rho + \frac{e_1 y_2 - e_2 y_1}{e_2},$$

where ρ is the resistance of the shunted rheostat. If e_1 equals e_2 and y_1 equals y_2, the whole term containing y_1 and y_2 be-

comes zero at all temperatures, whence we realize complete compensation for the leads. The resistances in all the arms of the bridge remain constant, giving, therefore, constant galvanometer sensibility.

The several components constituting the shunt are indicated at one side, and are made up of the following connectors between P_1 and P_2:

1. The shunt r; resistance $= ar$, in which a is the resistance of one unit of the bridge wire and r is a number representing the bridge wire units in the shunt.
2. Part of the wire $s - t$; resistance $= a(s - t)$.
3. Slider arm and contact resistance; assume resistance $= ac_0$.
4. Part of the bridge $n + t$; resistance $= a(n + t)$.

Numbers 3 and 4 are in parallel with each other and the two are in series with No. 2.

Let $ac =$ the joint resistance of Nos. 2 and 3. Then

$$ac = \frac{ac_0(n + t)}{c_0 + n + t} \tag{4}$$

The whole resistance of the shunted connection becomes

$$\rho = \frac{ar\left(\frac{c_0(n + t)}{c_0 + n + t} + s - t\right)}{r + \frac{c_0(n + t)}{c_0 + n + t} + s - t}$$

It is obvious that so long as c_0 has an appreciable magnitude, then ρ is a complex function of the form

$$\rho = \frac{a' + b't - t^2}{m' + n't - t^2}\, ar.$$

Retaining the simple expression ac for the joint resistance of Nos. 2 and 3, and substituting the value of ρ in the equation of the bridge we get an equation of the same form as (2) with some differences in the constants, viz.,

$$R = \frac{B(r + s + c) - ar(s + c) + (ar - B)t}{r + s + c - t}. \tag{5}$$

If the slider arm of the shunted rheostat is given some sensible resistance, then c becomes a complex function of t, and R becomes a still more complex function of this form:

$$R = \frac{A' + M't + \rho t^2}{N + Qt - t^2}.$$

Nothing is to be gained by this great complexity in the present problem, and we shall therefore avoid all of it by reducing the resistance in the slider arm to the smallest practicable amount; that is $ac_0 = o$, $\therefore c = o$ and (5) reduces to

$$R = \frac{A + Mt}{N - t} \tag{6}$$

in which

$$\begin{aligned} A &= B(r + s) - ars \\ M &= ar - B \\ N &= r + s \end{aligned} \tag{6a}$$

While the form of (6) is identical with (3), the constants A, M and N represent different elements of the bridge.

In the case shown in Fig. 4 we have the shunted rheostat in series with B. The bridge ratios are

$$\frac{R + y_1}{B + y_2 + \rho} = \frac{e_1}{e_2}$$

and since $e_1 = e_2$ and $y_1 = y_2$,

$$R = B + \rho.$$

Making the resistance of the slider arm zero as before we get

$$\rho = \frac{ar(n + t)}{r + n + t}$$

in which we note that t is positive and n takes the place of s.

We have in this case for the final equation,

$$R = \frac{A + Mt}{N + t} \tag{7}$$

in which

$$\begin{aligned} A &= B(r + n) + arn \\ M &= B + ar \\ N &= r + n \end{aligned} \tag{7a}$$

From all the foregoing, it follows that the bridge equation is either a linear equation or an equation of the form

$$R = \frac{A + Mt}{N \pm t}. \tag{8}$$

The three constants, A, M and N, are entirely arbitrary in so far as the mere fabrication of the bridge is concerned, and can be given almost any values we please. Therefore, by exercising a proper choice in the manner of connecting up the bridge and of the resistances in the arms, that is, the values of the constants A, M and N, the bridge scale can be fitted to almost any kind of resistance thermometer, whether its resistance changes with temperature by a linear law or according to some curve, either convex upward or downward. Indeed, if it seemed desirable, the greater complexity resulting from placing definite resistance in the slider arm of the shunted rheostat could be availed of, and the bridge scale could thus be adapted to highly complex laws of variation in resistance in the thermometer arm of the bridge.[1]

A few examples will suffice to illustrate how easily a bridge can be made up to fit a given thermometer.

EXAMPLE 1.—Calculations of the elements of an ordinary slide wire bridge; Fig. 2; nickel ribbon, Spiral III; quadratic equation:

$$R = 12.506 + 0.06252t + 0.0000695861t^2.$$

We take three values of R from this equation at temperatures selected arbitrarily within the range of the bridge scale of temperature, say, for example, at $-10°$, $+20°$ and $50°$. A least square computation involving several values of R might be resorted to, but the slightly closer coincidence of curves possibly secured by such a course does not justify the greatly increased labor.

$$\begin{aligned} \text{At} -10° \quad & R = 11.888 \\ \text{At} +20° \quad & R = 13.784 \\ \text{At} \quad 50° \quad & R = 15.806 \end{aligned}$$

Introducing these values in the bridge equation,

$$RN - Rt = A + Mt,$$

and solving we get,

$$R = \frac{11917.1 + 47.069t}{952.86 - t}$$

[1] See note at end of article.

By the aid of equations (3a), remembering that $n = 20$, $s = 60$, and assuming that the lead resistance $y = 0.05$ ohms, we find:

B = resistance of balancing coil = 46.969 ohms
$e_1 = 234.47$, $e_2 = 892.86$ } temperature units on the bridge wire.

If we make the slide wire side of the bridge have the same average resistance as the thermometer and balancing coil say 60.853 ohms, we find:

Whole bridge scale $= n + s =$	80	temperature units =	4.032 ohms
$e_1 =$	234.47	temperature units =	11.818 ohms
$e_2 =$	892.86	temperature units =	45.003 ohms
Total =	1207.33	temperature units =	60.853 ohms

that is, each unit of the actual bridge wire must have a resistance of 0.0504 ohms, a result easily controlled, if necessary, in the present case by a shunt across the slide wire proper.

The residual errors of the indications of such a bridge and thermometer, including effects of lead resistance, are less than 0.04 of a degree over the whole range of the scale, except at the extreme ends.

EXAMPLE 2.—Calculation of elements of bridge for thermometer No. 39, using shunted slide wire in series with thermometer; Fig. 3; equal ratio coils:

TABLE III.

ACTUAL MINUS INDICATED TEMPERATURES BY THE BRIDGES OF EXAMPLES 1, 2 AND 3.

Temp. °C.	Corrections spiral III slide wire		Corrections therm. No. 39; shunted wire		Corrections Plat. therm. B. S. No. 478; shunted wire	
	Resist. ohms	Temp.	Resist. ohms	Temp.	Resist. ohms	Temp.
−20	+.001	+.02	+.013	+.04	−.00018	−.009
−10	0	0	0	0	0	.....
0	−.001	−.02	−.006	−.02	−.00001	.....
+10	−.001	−.02	−.004	−.01	−.00001	.....
20	0	0	0	0	0	.....
30	+.001	+.02	+.004	+.01	0	.....
40	+.001	+.01	+.006	+.02	0	.....
50	0	0	0	0	0	.....
60	+.007	+.10	−.016	−.04	−.00001	.....

The value of A, M and N are computed as in example 1. Then, with equations (6a) we get,

B = resistance of balancing coil ..... = 114.29 ohms
ar = resistance of shunt ..... = 319.98 ohms
a = resistance of wire per degree of scale = 0.3270 ohms
$a(n+s)$ = resistance of whole scale..... = 26.161 ohms.

As we have already stated, there are great advantages in this arrangement in that the effects of lead resistance are perfectly compensated by a system of two equal leads and a third wire for battery, and the resistance in the arms of the bridge remain constant contributing to constant sensibility of the galvanometer. Some difficulties of construction are recognized in order to satisfactorily overcome questions of contact resistance on the bridge wire, and the exactness necessary in the adjustment of the resistance of the slide wire itself.

We shall give but one more example to illustrate the application in the case of platinum thermometers and to wires with a temperature resistance curve concave downwards.

EXAMPLE 3.—Bridge for platinum thermometer B. S. 478; shunted slide wire in series with the balancing coil; Fig. 4; equal ratio coils, and effects of lead resistance wholly eliminated with three wire leads:

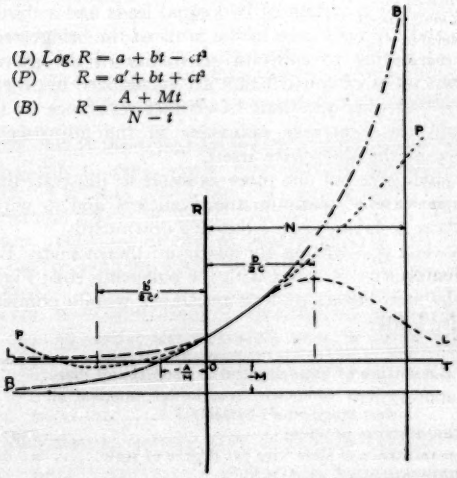
B = resistance of balancing coil = resistance of thermometer computed from bridge equation at lowest temperature of scale ..... = 4.7500 ohms
ar = resistance of shunt ..... = 135.47 ohms
a = resistance of slide wire per degree of scale..... = 0.02040 ohms
$a(n+s)$ = resistance of whole scale..... = 1.63184 ohms

In the absence of other data, this thermometer is taken to illustrate the application to platinum thermometers, but its resistance is much too small to warrant its use in the manner contemplated; that is, in most practical cases, a thermometer of much higher resistance could just as well be used and would give better results.

Table III gives the temperature errors resulting from the use of the bridge made up in accordance with the mathematical theory set forth. These residuals are simply the actual resistance of the thermometer (computed by the logarithmic, quadratic, or other

equation, assumed to exactly represent the change of resistance with temperature) minus the resistance computed by the bridge equation, the differences for greater clearness being expressed in both resistance and temperature units. Those familiar with bridge constructions will recognize that the residuals introduced by the mathematical relations employed are mostly of a much

FIG. 5.



smaller magnitude than the unavoidable errors of adjustment of the resistances and elements of a bridge.

It may be easily shown that the customary methods of constructing indicators for resistance thermometers by the use of a differential galvanometer are fully comprised within the scope of the mathematical analysis herein employed and resistances that will give direct reading temperature scales for such instruments can be computed in much the same manner as illustrated for bridges.

NOTE. It may seem in the foregoing that we actually use the bridge equation

$$R = \frac{A + Mt}{N \pm t}$$

in preference to any other for expressing the relation between the temperature and resistance of the thermometer we employ. This of course can be done and the constants can be computed directly from the temperature and resistance measurements on the thermometer. Such a procedure should, however, be restricted to a relatively narrow range of temperature. Experience, moreover, indicates that the parabolic and logarithmic equations represent the relations between the temperature and resistance of both platinum and nickel over a considerable range of temperature better than the bridge equation. The general character of the several curves for nickel thermometers are shown in Figure 5. The methods of Analytical Geometry readily indicate that the bridge equation

$$R = \frac{A + Mt}{N \pm t}$$

is the equation of a rectangular hyperbola. The asymptotes are parallel to the axes at distances $\pm N$ and $\mp M$ according as the sign in the denominator is $-$ or $+$.

A Search For Potash.—The amounts appropriated for the work of the United States Geological Survey for the fiscal year ending June 30, 1912, include an item of $40,000 " for chemical and physical researches relating to the geology of the United States, including researches with a view of determining geological conditions favorable to the presence of potash salts." It is understood that one-half of this appropriation will be devoted to the potash exploration.

Borax in the United States; Mines All in California.—California produces all the borax mined in the United States and is now supplying nearly all the domestic demand. The principal mine is in the Death Valley region, in Inyo County. Another mine is in Los Angeles County.

The mineral mined is colemite, or borate of lime, most of which is shipped crude to Alameda, Cal., or Bayonne, N. J., for refining.

About half the product is consumed in enameling kitchen ware, but new uses for borax are found every year.

A leaflet on the production of borax in 1909, by Charles G. Yale, has just been published by the United States Geological Survey.

American Society of Mechanical Engineers.—The sixty-third meeting of the Society will be held in Pittsburg, Pa., from May 30th to June 2d, inclusive. The Society has not met in that city since 1884.

An executive committee consisting of E. M. Herr, Chairman, George Mesta, J. M. Tate, Jr., Chester B. Albree, D. F. Crawford, Morris Knowles and Elmer K. Hiles, Secretary, will have charge of the Pittsburg meetings. It is expected that from 300 to 400 members and ladies will be in attendance. There will be professional sessions when papers will be read and discussed. There will also be inspection trips through the leading local industrial establishments besides automobile trips through parks, a visit to Carnegie Institute, Memorial Hall, etc.

The headquarters of the Society are in New York City and Col. E. D. Meier of St. Louis is President this year.

Modern Abrasives Harder Than the Old Ones.—Carborundum and alundum are among the latest of modern abrasives. They are made at Niagara Falls by means of the electric power generated by the cataract. Another new abrasive made there is aloxite, which is used for grinding steel tools. The manufacturers state that it does not greatly heat the tools nor draw their temper. Samite, another new abrasive made at the same place, is used for cutting or abrading aluminum. Its cutting surface does not glaze or fill when it is used on aluminum or other fibrous metals.

STATISTICS FOR 1909.—The United States Geological Survey has published a pamphlet by W. C. Phalen on the production of abrasive materials in 1909, giving statistics of the output and value of burrstones, millstones, grindstones, oilstones, corundum, emery, pumice, and other natural abrasives for that year, and of the artificial abrasives carborundum, alundum, and crushed steel. The pamphlet is an advance chapter from the Survey's volume entitled "Mineral resources of the United States, calendar year, 1909."

Decomposition of Cyanides in the Soil. H. KAPPEN. (*Frühlings Landw. Zeit.*, lix, 19.)—The decomposition of calcium cyanimide in the soil can be caused by inorganic catalysis, though the co-operation of micro-organisms is also possible, and it is impossible at present to distinguish between the action of the two factors. Different soils behave very differently towards cyanimide, probably because in one soil the decomposition is mainly caused by chemical agencies and in another soil by biological effects. Extended experimental studies have shown that certain metallic hydroxide gels, particularly those of manganese and iron, act catalytically in promoting the conversion of cyanimide into carbomide. Silica and alumina gels and the other silicate gels, assumed to exist in soil, have no influence.

THE POLARIZATION OF RÖNTGEN RAYS FROM AN ANTICATHODE OF SILVER.

BY

F. C. MILLER,

Department of Physics, Pennsylvania State College.

THE discovery of the polarization of Röntgen rays was made after a consideration of the ether pulse theory: for this theory led investigators to expect a greater intensity of the rays in a direction at right angles to the cathode stream than in the direction of that stream. C. G. Barkla,[1] from a series of experiments on secondary rays concluded that the primary beam is partially polarized. H. Haga,[2] by use of the photographic method, decided that no polarization of the primary rays exists; but J. Herweg,[3] by use of the same method, came to an opposite conclusion.

W. R. Ham,[4] by use of the ionization method and direct experiments on the primary rays, not only showed that the intensity of the rays is a maximum in a direction at right angles to the cathode stream, but that the intensity decreases symmetrically on either side of this plane.

Dr. Ham's experiments were made on Röntgen rays from an anticathode of lead. From his data we should expect polarization of rays from other metals. Also from his results on the absorption of these rays by silver and tin we should think that there is a difference in the polarization of rays from silver as compared with those from lead and that those from silver are polarized to a greater extent.

Therefore the aim of the following investigations has been,—

1. To learn if the rays from silver be polarized.

2. To learn if the polarization differ from that of the rays from lead,

3. and if so, to what extent and in what manner.

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[1] C. G. Barkla, Phil. Trans. A., 204, p. 467.

[2] H. Haga, Ann. d. Phys., vol. xxviii, p. 439.

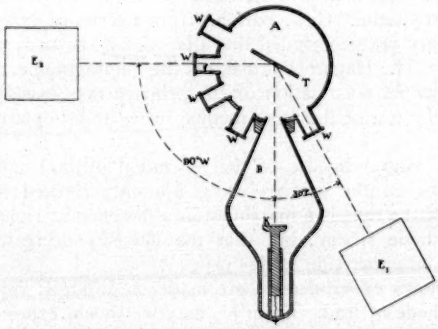
[3] J. Herweg, Ann. d. Phys., vol. xxix, p. 398, 1909.

[4] W. R. Ham, Phys. Rev., vol. xxx, No. 1, Jan., 1910.

ARRANGEMENT OF APPARATUS.

The apparatus used was practically the same as that used by Dr. Ham. The arrangement for testing the Röntgen rays for polarization, which was the most important part of the apparatus, is shown in Fig. 1. A is the tube constructed with windows W, W, etc., each cut from the same sheet of glass of uniform thickness to eliminate the error that would arise from unequal absorption by the walls of an ordinary X-ray tube. B is a side tube containing the cathode K. The secondary rays that originate in it are cut off by thick lead shields. The two electroscopes E_1, E_2,

FIG. 1.



were of the ordinary type for this kind of work. They were charged to a potential of about 340 volts by means of a battery of dry cells, and their discharges read by means of micrometer microscopes.

Another type of tube,[5] used during the early part of the experiment, was constructed from a selected glass cylinder of very nearly uniform thickness. Hereafter we shall call the tube just described No. 1 and the tube with windows No. 2. The target T, one side of which is lead and the other silver, is carefully balanced on a post at the centre of the tube.

The general arrangement of the apparatus is shown in Fig. 2. S, S, are the terminals of a Holtz machine, motor driven. Near

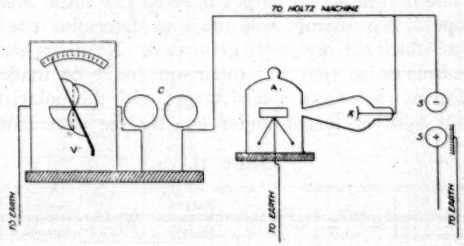
[5] See article by W. R. Ham, Phys. Rev., No. 1, Jan., 1910, Fig. 2a.

the positive terminal is a set of points connected to ground. The negative terminal is connected to the tube and to an air condenser which is in series with a Thompson electrostatic voltmeter. The voltmeter and tube are connected to ground.

PROCEDURE.

The two electroscopes were first tested over long periods of time for rates of natural leak. Then their relative rates of discharge were obtained. This was done at first by placing them side by side about four metres from an ordinary X-ray tube and taking their discharges. Later in the experiment they were placed opposite the two windows at 30° E. and 30° W. of the

FIG. 2.



cathode stream. The target was placed perpendicular to the cathode stream and hence the absorption within the target was necessarily the same for both sets of rays. Since the rays that reached the electroscopes made equal angles with the cathode stream the intensities of the two beams should be equal. Therefore the rates of discharge had to depend upon the discharge constants of the electroscopes. As a check on these readings the positions of the electroscopes were reversed but, no change being noticed, the one position was used thereafter. A sample set of readings for determining the relative rates of discharge is given in Table I.

The electroscopes were tested after each set of readings, and it was found that the ratio of the rates of natural leak and the ratio of the rates of discharge were nearly the same. In fact the leak was so small and of such a nature as to cause no error

if neglected. Whenever a leaf was changed the ratio of the rates had to be redetermined.

To determine the relative intensities of Röntgen rays in directions of 30° E. and 90° W. of the cathode stream the electroscopes were placed at equal distances from the axis of Tube

TABLE I.

No. 1 at 30° E.	No. 2 at 30° W.	Ratio $\frac{\text{No. 2}}{\text{No. 1}}$	No. 1 at 30° E.	No. 2 at 30° W.	Ratio $\frac{\text{No. 2}}{\text{No. 1}}$
75.5	84.7	1.121	60.8	68.6	1.126
65.6	74.9	1.141	73.6	84.6	1.149
70.8	80.9	1.143	71.4	80.7	1.130
71.7	80.8	1.136	70.8	80.1	1.131
69.3	78.8	1.137	76.0	84.4	1.115

No. 1. The normal to the target bisected the angle between the electroscopes. No attempt was made to determine the absolute potential at which the rays were generated. Readings were taken on the voltmeter so that a comparison could be made of the polarization of rays from a lead target with the polarization of those from a silver target under exactly the same conditions.

TABLE II.

	No. 1 at 30° E.	No. 2 at 90° W.	Ratio $\frac{\text{No. 2}}{\text{No. 1}}$	No. 1x Ratio	Per. cent. change in intensity	Reading of voltmeter
Lead	54.6	72.3	1.14	62.2	13.9	30
	64.1	83.1	1.14	73.1	12.6	28
	65.2	89.7	1.14	74.4	17.0	28
	57.6	76.3	1.14	65.7	14.0	35
	61.5	83.9	1.14	70.2	16.3	34
	42.1	58.2	1.14	48.0	17.5	25
Silver	68.3	90.9	1.14	77.8	14.4	36
	65.1	87.6	1.14	74.2	15.3	35
	65.6	89.7	1.14	74.7	16.8	28
	68.2	84.4	1.14	69.7	17.4	27
	62.5	87.4	1.14	71.2	18.5	28
	61.7	86.3	1.14	70.3	18.5	28

A set of readings was taken with rays from lead; then the target was swung around and a set taken using the silver side of the target. A few of the readings and calculated polarizations are given in Table II.

Because it was known that the cylinder from which the tube was constructed was not quite uniform in thickness the experiment was continued with Tube No. 2. Since this tube was pro-

vided with uniform windows and since all rays except those from the two windows in use were screened off, the data is more reliable.

The results of experiments with this tube are shown in Table III.

TABLE III.

	No. I at 30° E.	No. 2 at 90° W.	Ratio $\frac{\text{No. 2}}{\text{No. 1}}$	No. IX Ratio	Per. cent. change in intensity	Reading of voltmeter
Lead	66.3	81.8	1.113	73.8	9.8	22.0
	72.0	88.1	1.113	80.2	8.9	22.5
	72.2	88.6	1.113	80.3	9.4	22.0
Silver	69.1	85.4	1.113	76.7	10.0	22.5
	69.9	88.1	1.113	77.6	11.7	22.0
	67.2	84.2	1.113	74.6	11.2	21.5
	68.0	85.3	1.113	75.7	11.3	21.5
Lead	72.3	91.8	1.106	79.9	12.9	20.8
	73.8	95.6	1.121	82.7	13.5	20.0
	72.5	93.2	1.121	81.3	12.8	20.0
	72.1	92.3	1.121	80.8	12.5	20.6
	75.5	92.6	1.100	83.0	10.3	20.5
	74.8	92.6	1.100	82.3	11.6	20.6
Silver	75.7	94.8	1.100	83.3	12.1	20.0
	70.0	87.1	1.100	84.7	11.6	20.5
	72.9	90.9	1.100	80.2	11.7	20.8
	66.3	84.6	1.100	73.9	12.8	20.8
	72.3	91.8	1.100	79.9	12.9	20.8
	75.7	93.8	1.100	83.3	11.2	20.0
Lead	63.5	83.5	1.113	70.7	15.3	21.5*
	64.2	84.2	1.113	71.4	15.2	22.0
	57.3	76.8	1.113	63.6	17.0	21.0
	67.0	86.9	1.113	74.6	14.2	22.0
	66.7	85.3	1.113	74.0	13.2	22.0
	63.7	82.3	1.113	70.8	13.9	22.0
Silver	64.2	83.7	1.113	71.4	14.7	22.0
	65.8	85.0	1.113	73.2	13.9	22.0
Lead	23.7	32.2	1.115	26.3	18.0	16.5
	60.2	79.1	1.115	66.2	16.7	16.8
	59.7	80.3	1.115	66.6	17.0	16.0
	54.7	75.6	1.115	61.0	19.3	16.2
	60.5	80.4	1.115	67.4	16.1	16.5
Silver	61.2	83.8	1.115	68.3	18.5	15.0
	65.1	83.8	1.115	72.6	13.4	20.0
	68.2	86.4	1.115	75.7	12.3	22.5
	59.0	79.5	1.115	65.5	17.6	16.5
	62.7	84.1	1.115	69.6	17.9	17.9
	68.2	90.9	1.115	75.7	16.5	16.2

* The distance between the condenser plates was made less; hence the following readings of the voltmeter indicate a lower potential than the above.

It appears that within experimental error no difference exists in the polarization of Röntgen rays from a lead target and a silver target.

In conclusion I wish to thank Dr. Ham for suggestions and advice throughout the work and Mr. W. P. Davey for assistance in arranging apparatus and taking readings.

Manganese Steel. ANON. (*Eng. Record,* lxiii, 63.)—Wrought manganese steel is now carried in stock in the form of rounds, flats, plates, sheet bars, billets and blooms. The rolling and forging of manganese steel was declared to be impossible for some years after the Taylor Iron and Steel Co., had established manganese steel castings on the market. Nevertheless the Manganese Steel Rail Co., has developed a process of rolling and forging. It will be observed by those who look into the details of the conquest of manganese that the real work has been done by men of distinction as students and savants, like Prof. Howe and Dr. Cushman, rather than by mill-men, whose experience makes them question the practicability of methods not founded on the physical facts familiar to them.

The Absorption of Nitrogen by Aluminum. ANON. (*Brass World,* vii, 1.)—Aluminum has several properties diametrically different from other metals, and one is its power of absorbing nitrogen from the air. This absorption is believed to be responsible for blow-holes and a reduction in tensile strength. This absorption is clearly shown by wetting a mass of aluminum skimmings, which will, in a short time, smell strongly of ammonia. In melting aluminum it is not customary to cover it, *e.g.* with charcoal; hence the molten aluminum has ample opportunity to absorb nitrogen. Hitherto oxidation has been considered the cause of injury to this metal when overheated, but undoubtedly the absorption of nitrogen is another factor.

Pendular Hardness Gauge. DR. ING. J. KIRNER. (*Amer. Mach.,* xxxiii, 972.)—This hardness testing machine is constructed in the form of a pendulum. The hammer carrying the striking truncated cone is swung by a rod from a post provided with levelling and other adjustments. The bar of steel to be tested is held in a vise presenting its end to the hammer. The hammer is raised so many degrees measured on an arc scale, and the extent of the rebound is measured. The end of the bar requires little preparation and the hardness is determined over the whole cross-section. It is said to be accurate for practical purposes.

Effect of Cold on Plating Solutions. ANON. (*Brass World,* vii, 2.)—In cold weather there is difficulty in obtaining a good deposit as rapidly as in summer, owing to the low temperature of the plating solutions, which will not work well when down to 30° F. or 40° F. The best results are obtained by maintaining the solutions at a uniform temperature all the year round or about 70° F., which can be easily done by a steam-coil. Cyanide copper and brass solutions are more affected by cold than silver or acid copper solutions. Nickel solutions are considerably affected, though not so much as cyanide copper or brass solutions.

NATURAL AND ARTIFICIAL DRAFT.*

BY

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Boston.

My subject to-night falls naturally into two parts, in the first of which we will consider the properties of Natural Draft, and my remarks on this will repeat in part a similar presentation of the same subject which I have given elsewhere.

NATURAL DRAFT.

We see in nature the fire burning on the open ground, making its own natural draft produced by the current set up by the ascending heated gas of lighter density rising therefrom. If the wind blows against the fire it is greatly kindled and the heat becomes intensified, but when the air is quiet again, the combustion becomes more sluggish. Hence primitive man no doubt imitated the wind with his lungs or by fanning. The discovery of confining the heat up a vertical tube to make a better combustion we can also suppose to be within the limits of this period, although the uses made of these applications were not based upon any scientific study or knowledge of the causes producing these effects in the way we are endeavoring to understand and apply such principles more intelligently in our discussion here this evening.

The term "natural draft" as in general use at the present time we understand to refer to the draft produced by the tube or chimney unaided by any other means and for a while we will confine ourselves to this restriction of our subject. The importance of a good draft is becoming more appreciated as the demands for greater steaming and the closest economy in generating, are found to depend ultimately upon the ability of the chimney.

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* Presented at the Meeting of the Mechanical and Engineering Section, held Thursday, February 23, 1911.

Nearly every treatise pertaining to chimneys and natural draft will be preambled with the following statement: "The natural draft obtainable from a chimney depends upon the column of gas inside the chimney being lighter than the air outside." This, however, is not altogether the sole cause in producing draft, as a wind blowing over the chimney produces considerable suction without the inside air or gas being heated at all; in fact, I have tested chimneys where I have obtained a slightly higher draft pressure than the temperatures and height figured to be possible. As there is always some wind in nature, this supplemental aid to the scientific quantity of draft that we have produced by heat, is of importance and of considerable value, many localities thus favored obtaining a draft equivalent to perhaps 25 or 50 ft. more of chimney height; nevertheless, as the wind is such an uncertain element we have to fall back in foresighting our calculations to what may be reliably obtained from an assumption of height and temperature conditions for producing a given draft by the stack.

There are only two dimensions to be determined, the height and the area, and we will consider first the matter of selecting the chimney height. A proper height is of the greatest importance as this produces the dependable pulling force. This force must be sufficient to overcome friction through the grates, and this quantity varies according to design and percentage of air opening.

Through the coal, which depends upon its depth, quality, tendency to clinker and the intelligence of the firemen.

Through the boiler, which is more or less according to its general type and bafflings.

Through the flues and chimney, which is affected by their size and shape as whether square or round and the crooks and turns and whether of brick or iron, the former making for more resistance.

Consideration for the adequate draft to cover these factors is no simple matter, but nevertheless should be squarely met.

The providing a good height of stack to produce a strong, vigorous draft involves some expense, but this expense can be offset by the use of fewer boilers at a less cost for a smaller building, as well as in the saving for foundations and piping.

It is becoming generally appreciated that there is also a con-

siderable economy in running with fewer boilers, due more or less to the following causes:

First.—There is less expense for banking same at night, as it costs no more to bank at night a highly developed boiler than for one running under or at normal rating.

Second.—With an intensity of fire the gases are more completely burned to CO_2. A low flue temperature does not indicate that the gases were completely burned, and in fact it generally shows that they were not, as well as having an excess of air.

Third.—The better circulation set up and this more rapid circulation of steam making for better boiler efficiency. I remember in my reading of an interesting account of a discussion on this matter. I think it was before the New York Railroad Club by some English engineers, going into the matter of heat transferrence from the fire to water in passing through iron plate or boiler tube, in which they maintained that experiments had absolutely proved that there was a better transferrence of heat to ebullating water than to still water, and abroad they have carried this out logically in firing special boilers to heat the water for the steam making boilers to enter as near their steam making point as possible.

Fourth.—Although aside from any use of the Economizer there is generally a greater gain to be had from an intensive furnace, it is apparent that the economizer value is increased greatly in bringing to a conclusion the all around efficiency to be had from intensive firing by reducing the heat in the flue down to the lowest point allowable to sustain draft, thereby making for practically as perfect utilization of the heat that is to be had.

Fifth.—Less smoke produced. A good draft is necessary to the successful operation of any stoker, hence given the same co-operation to ordinary grates, less smoke will also result if combined with some intelligence that the firemen does not blanket the whole of his fire with green coal at a single operation.

Should some one rise to prove the opposite, I would be prepared to say that where experience has been found against attempting such heavy coaling and overrating (forcing, if you please) and where better economy was found to be had by running more, rather than fewer boilers, that such cases will usually be found where a poor draft exists, requiring more boilers to be used to get a larger grate area to spread the coal on thinner.

Speaking of forcing, the use of any chimney is to force the fire. So every fire not left to smoulder or burn on the open ground is a forced fire. If you considered your boiler merely as a large kettle of some unknown size, whatever you could get out of it would be the capacity it was good for. Suppose you could get twice as much performance, or more than before, from any kettle, you would not consider you had caused any strain or injury nor would you; hence the word "forcing" in the sense of working beyond or close to its safe usage as would be in mind by the use of the word applied similarly to an engine does not exist. So long as the limit of safe pressure is never exceeded, the safe output of steam is unlimited.

It has come about in practice that the purchaser wishing to produce 1000 boiler h.p. that the builders generally furnish him 10,000 sq. ft. of heating surface or 10 sq. ft. per horsepower, as it is a safe measurement to use with a very ordinary draft. But whether the purchaser obtains 1000 h.p. or twice that, out of the size he has bought, is purely a matter of supplying heat enough and that is practically limited only by the draft strength to burn the requisite coal on the grates. As stated before, conditions may make it otherwise, as with a definite chimney draft installed, the efficiency may be better below the builder's rating, at rating, or above rating.

So where a person is planning a new chimney, his course for determining the size should include consideration of the following:

FOR THE HEIGHT.—1. The local advantages of the situation, as to exposure to wind and its general climatic dependence. As a general statement a high elevation at start for the foundation is an advantage, still it is not necessarily so, as sometimes a valley situation may be so placed that it may have an unusually strong current of wind drawn through same and seldom troubled with cross winds which would cut off the sweep above the chimney, but ordinarily the valley location demands a higher chimney to protect the plant against the loss of draft it would have, were it not hemmed in.

2. The placement distance of the furthest boiler or boilers, relative to the stack.

3. Type of boilers and grates.

4. Quality and depth of coal.

It is universally taught that "draft" varies as the square

root of the height, but this use of the word "draft" applies only to the capacity which is more a matter of area, as I will show later. The prime thing is a proper height, as it is this factor—adequately ascertained—that gives you the assurance of a provision for the essential force or pull to run your plant at a reduced expense for boilers, for their setting, piping and size of house, and with a better economy to boot. I wish you to note the distinction between draft pressure and draft capacity; the word "draft" is used too indiscriminately to either function and is unscientific as well as confusing.

Chimneys give a draft pressure in direct proportion to their height, thus 200 feet gives twice the pressure of 100 feet and the pressure is the same for all chimneys having the same height whether the area varies between them as 1 or 50 sq. ft. in section; hence, if I have figured it for you on a reasonable assumption of 450° in your flue gases and tell you it is 0.6 of an inch with a stack 100 ft. high when the outside air is 60°, then you will know that to obtain 0.9 of an inch that 150 feet height would be required regardless of any area, and for 1.2 inches the height must be 200 feet and so on. Afterwards selecting the area to suit the volume from the expected amount of output.

This factor 0.6 of an inch per 100 ft. of height the writer believes is a safe basis, as in the winter time the outside air is colder, making for a still better result, and while in the summer it would be somewhat less by the outside air being hotter than the assumed 60°, yet the heating system is off so that the work will be usually somewhat less, and in addition you have two likely forces that will most always make the draft better than this given factor, namely, the assistance of the wind and more frequently hotter leaving gases.

Many papers have been written on the subjects of chimneys and drafts, generally developing abstruse or speculative theories. The most helpful and practical that I have come across was in a recent article by T. F. J. Maguire, which gave definite measures of draft resistances. (See Table I.)

Loss of draft in boiler setting he measures as 0.3 of an inch to Water Tube boilers, increasing to 0.4 of an inch with 50 per cent. overload. Of course he intends this to be used with some judgment in application to the special boiler in mind, as to its construction and bafflings. The writer believes Horizontal Return Tubular boilers will be found to require the same allowance

and the Manning and Vertical types half of this or 0.15 of an inch. You do not have to take any multiple of the factor by the number of boilers.

Loss of draft in breechings. Maguire allows 0.1 of an inch per 100 ft. of length to circular iron flues and 0.05 of an inch for each right angle turn. If squares or rectangular shape, increase the above 25 per cent. For brick flues increase the above 30 per cent. The writer would allow for the stack travel the same as for the breechings.

The supplying of these reliable factors for fixing chimney dimensions on an intelligent basis to meet the duty that will be required is of great service.

Let us see how the application of such factors would apply to a concrete case where we assumed we wished to burn 25 lbs.

TABLE I.—DRAFT PRESSURE REQUIRED IN FURNACE.

Kind of coal.	Pounds of dry coal burned per square foot of grate per hour						
	15	20	25	30	35	40	45
	Draft in inches of water						
Eastern bituminous coals	.12	.16	.20	.27	.34	.42	.52
Western bituminous coals	.15	.20	.25	.33	.42	.52	.65
Semi-bituminous coals	.15	.20	.28	.37	.48	.60	.80
Anthracite buckwheat, No. 1 and larger	.45	.70	1.00				
Anthracite buckwheat, No. 2 and No. 3	.75	1.30					

of soft coal under Horizontal Tubular boilers with two right angle turns in the breeching.

Furnace draft for 25 pounds soft coal	0.2
[1]H. R. T. boiler	0.3
50 feet of steel breeching	0.05
Rectangular shape 25 per cent. additional	0.0125
Two right angles	0.1
Round brick chimney 150 feet	0.15
Brick surface 30 per cent. additional	0.045
Total draft required	0.8575

[1] Resistance increases with velocity, if therefore 25 pounds per square foot would develop a considerable amount above rating, add a third to the boiler resistance. In the above it would therefore be 0.4 for the H. R. T. instead of 0.3 for its normal. This addition of increase will probably cover the flue resistance as well.

Or approximately 0.9 of an inch, and as we can get 0.6 of an inch of pressure per 100 feet of height, then a 150 ft. stack should provide the total pressure needed. Notice that this stack height is indifferent to any size or amount of horsepower output, except as more boilers would require allowance for longer flue travel which would be very slight.

I would like the opinion of others on this showing, because if general practice is shown to coincide, it will be of much value and equally so if more reliable quantities can be established. I know at the outset that some will claim to have a 150 ft. chimney and cannot burn at this rate, and if so, the cause may be found due to excessive area absorbing the heat needed to produce the expected draft pressure or to some other accountable reason.

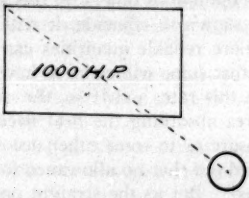
It may be pointed out that no allowance for economizer draft effect has been listed. But as the straight open-passage type of economizer has generally a greater free area than the flue, it can be reckoned on its length as for flue distance. Further, you must know that the top layers on the coal bed make for a greater proportional resistance, so an economizer saving 10 per cent. of coal, would ease the fuel resistance to produce the same output of steam, thus practically offsetting any effect of its own resistance, while the owner is 10 per cent. of coal in pocket with a proportionate draft pressure needed to accomplish the same output. This has proved universally true through a period of over half a century, so that the exceptions are now known to be due either to its faulty installation or fault in the design and size of the economizer selected.

Until further tests have been made to determine the actual pressures required for the usual run of commercial qualities of coal depths on grates, these figures may be treated with some caution, yet faulty as they may be, they will prove in the main quite trustworthy as a deviation will probably be found to be offset by some other, so if the boiler makes more friction, the coal perhaps will prove less. Hence, I believe determining your chimney height on a basis of such quantities, better than making a vague guess as it is generally being done now, and no one will welcome corrections to the foregoing calculations more agreeably than myself, knowing a true schedule would be of the greatest value to every power producer.

You observe the size of plant and number of boilers, except

as they effect the flue distance, have no consideration in this matter of height determination. That there is no definite height to correspond with a given size of horsepower will be seen if a stack of sufficient height to suit a 1000 h.p. plant is arranged as in Fig. 1.

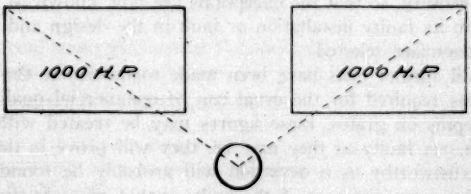
FIG. 1.



That the same height should be equally sufficient with a proportional increased area for 2000 h.p. arranged as in Fig. 2.

As the length of pull to the furthest boilers is no greater a demand than that for the single 1000 h.p., so too, the same height would be satisfactory to 4000 h.p. of boilers arranged as in Fig. 3.

FIG. 2

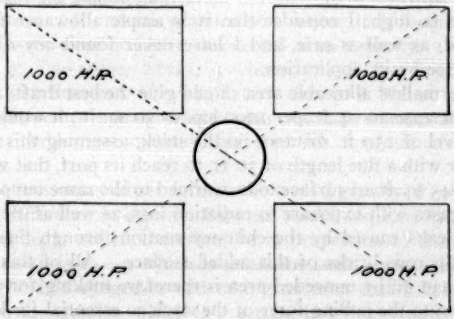


As the gases travel about 70 feet a second, a distance of 20 feet more or less is negligible in the flue resistance as is the fact of using an Economizer, presuming the Open Tube style is used with a free area equivalent or greater to the flue giving a straight-way passage. The prime requisites therefore for determining the proper draft pressure are the coal depth and the boiler type.

FOR THE AREA.—The size of the plant determines the area. The boiler horsepower of the output should not be considered in determining the height as we have just seen and as is mistakenly being done now, with rare exception, but it is the sole basis for determining area.

The selection of a suitable area to a chimney is as frequently a guesswork dimension as for selecting the height. Some have a pet rule of making it proportionate to the grate surface, regardless of the fact that if twice as much coal is burned in one case as in the other, it would call for twice the flue area, because having

FIG. 3.



double the amount of gas volume of the other. Others figure up all the tube area in their Horizontal Return Tubulars or Mannings or measure up the outlets of the water tube, etc.

As to build to good height costs so much more in proportion than for area, it is a common fallacy to curtail on the former and increase the latter. Thus for 1500 h.p. the owner provides himself with a stack of a height suitable for only 1000 h.p. and uses an area good for two or three times this amount and wonders why, after putting up a stack "said to be good for perhaps 3000 h.p." he has difficulty in getting 1500 h.p. and has to have recourse to artificial aid. The theoretical area required for 1000 h.p. of boilers with a stack only 100 feet high is but 7 square feet under ordinary conditions. In my own practice, I usually allow

20 sq. ft. for a single 1000 h.p. boiler installation as being ample for this amount of horsepower at normal running and also as allowing for the reasonable increased growth of plant and overload. For two or more thousand horsepower I reduce this area allowance about 10 per cent., increasing the reduction on very large plants to perhaps 20 per cent., keeping 16 sq. ft. as well within a safe limit per 1000 h.p. where the plant becomes several thousand. For smaller plants, say, 500 h.p., for instance, I would allow 12 sq. ft. which is then more than three times the theoretical area on the moderate basis of a height of 100 feet.

If the chimney is above 100 feet in height, the theoretical 7 sq. ft., requirement is still less, and as I say, I never take less than 16 sq. ft. of area, which is more than double the theoretical for 100 ft. high, I consider that it is ample allowance for any overload, as well as safe, and I have never found any difficulty in practice by its application.

The smallest allowable area should give the best draft, as were we to increase 20 sq. ft. per 1000 h.p. to 30 sq. ft., it would mean in a travel of 150 ft. distance up the stack, assuming this height, together with a flue length of 30 ft. to reach its port, that we have added 645 sq. ft. of surface to be warmed to the same temperature of the gases with exposure to radiation loss, as well as increasing the air leaks caused by the chimney suction through flue seams and the porous bricks of this added surface. All of this excess surface put on by unneeded area is therefore making for a great detriment to the pulling force of the stack so essential for keeping down the plant investment as well as for its economy.

On the same basis of conditions as for the 100 ft. stack to be used for determining the draft pressure, we find that 69 cubic feet will be passed per second per each square foot of area.

Assuming then our boiler horsepower requires as much as 4 pounds of coal per horsepower and while theoretically 12 pounds of air is needed to burn a pound of coal we will use 20 or plus the pound of coal involved,—21 pounds of gas or 84 pounds gas per boiler horsepower. So as calculation shows, we have therefore for 1000 boiler horsepower with a short stack of only 100 feet high, the startlingly small area of 7 sq. ft. actually needed. If the surface friction needs to be set off, surely 25 to 50 per cent. is ample allowance, and then as you think the plant may run above rating, or increase in the future, use your judgment as to

further percentage of increase to same; but do bear in mind that excess area beyond reasonable future requirements does not assist at all in pulling the needed air through the coal heaped on the grates.

Surely 4 pounds of coal per horsepower and 21 pounds of gas per pound of fuel are reasonably large factors, so if requiring actually only 7 sq. ft. per 1000 h.p., why such tremendous excess areas are invariably allowed, is a puzzle. I suppose it is done because it is cheaper to provide more area than the needed height and therefore we see something like a 2000 h.p. or more area with an inferior height provided to be used for only 1000 h.p. and proving in such cases that where the short stack height is a fault to begin with, it is made worse by hitching it together with an undue area. In actual practice the writer has found several stacks work close to their theoretical area capacity, as for instance at Lawrence, Mass., a chimney 128 feet high above grates with flue area of 9 sq. ft. took care of 6 Manning boilers in a satisfactory manner, developing 780 h.p. whereas the usual chimney tables recommend this size for approximately only 300 h.p.

The movement of air follows the law of gravity, $V = \sqrt{2gh}$. So the difference in capacity between stacks respectively 100 and 200 feet high would, therefore, be in proportion to their square roots, as 10 is to 14, which is small for such a great difference, so I ignore it altogether and taking an area that I know to be right to the smaller, which is 7 square feet theoretically and increasing this to 20 square feet for use in practice per 1000 h.p., for any height of chimney, I know it must be even more safe if there is a greater height than 100 feet. So I believe this is the largest area for best results and using any greater factor than 20 sq. ft. can only be detrimental to the draft force.

While I do not wish to deter those who have time and the disposition to figure a given chimney problem with accuracy, yet I believe the factors, 0.6 of an inch pressure per 100 feet of height and the area factor at 20 sq. ft. per 1000 h.p. for all heights, will be welcomed by many as safe quantities to work to in selecting the two required dimensions of a new chimney.

If you must add something for "good luck", put it on the height, as you stand to lose less on this, as the excess area will only come useful in a long distant future when the plant has

grown to it, as the 20 sq. ft. basis for area is nearly three times the theoretical and it provides sufficiently for all needs of reasonable increase.

I have seen too many plants handicapped by strained proportions for a great future, whereas when the future did arrive, it was entirely a different mill or a problem altogether dissimilar to any initial conception. In following the mill development for twenty years in New England, it has inclined me to believe that if I had the making of any new power plant layout, it would be my purpose to plan for the highest economy for the immediate needs, not extending farther perhaps than the next five years. This burdening a new plant to struggle under heavy fixed charges and loss in operating until the work develops to meet the initial undue proportion, is as bad as buying a man's suit for a boy because you know he is going to grow to it some day. Make things of right proportions to get the best economy for what you need now, and when success brings ample capital you can then easier afford to throw away the old plant, if you like, and start out with another up-to-date outfit. In our conceit at any present time, we lay out big schemes for additional future boilers of the same kind in a great shed of a building and what is found generally ten or fifteen years later, is a collection of big and little units, different makes, different piping systems, etc., with the same thing seen in the engine room and elsewhere.

Realizing the convenience of using the chimney tables in vogue, I hope my two factors of 0.6 of an inch per 100 ft. of height and 20 sq. ft. area per 1000 boiler horsepower will prove a simpler and better substitute, and when used with intelligent study and tabulation for the needed height for pressure, will make your future chimneys a better investment.

In regard to the character of the chimney construction in general use, the most efficient and handsomest, in the writer's opinion, is a well designed red brick or radial brick chimney with an inside core. The next selection would be such brick chimney without a core, following which would be a lined steel stack, with the unlined steel pipe the lowest in order. There is another advantage besides the better retention of heat, in having a core, as it can be taken out if more area is ever needed and in many cases this has been done.

Concrete chimneys are being built also, but some good en-

gineers are afraid of them as they claim that concrete is such a brittle substance that owing to wind vibration it will certainly in time open fissures through the thin shell, which will permit the entrance of moisture and combining with the sulphur gas destroy the reinforcing iron bonding the material.

To make my paper practical to those of my hearers who have chimneys already built, I would say that yours is a case of studying your conditions to see what you can best get from them and suggest that you try running your plant on as few boilers as possible. I believe the result will prove decidedly advantageous. You must have the engineer interested to give it a fair trial as it may mean a little better attention to fires to prove it out, because if you are troubled with weak natural draft you must break up the fires oftener and study closely to obtain more intelligent and more intensified firing.

In winter, if you are troubled with poorer draft than in summer, it is due to having the boiler room too tightly closed. If the firemen object to cold drafts from doors and windows, provide the air entrance from the top of the room.

Often the wind in certain directions, instead of assisting the draft makes for the contrary, which condition occurs when the wind is blowing in the direction towards the further boiler house door and this being kept open, the suction of air follows along in the same direction out through same, so that the end boilers nearest to the door have difficulty in getting their supply of air through the grates.

An unutilized excess of draft pressure is bad and the boilers should be fired as near the limit of draft as possible so as to prevent such excess, but there will at times be necessarily a considerable surplus pull by the wind producing a greater draft one time than another. That this excess draft is more common than otherwise is shown by the operation of the automatic regulation of dampers in the general run of plants, continually cutting off 25 to 50 per cent. and more of the available draft throughout the entire day. Of course as the plant is being run, the damper regulation makes for a great saving in preventing an undue excess of air through the grates, but the force should be put to work so far as possible to produce a more intense fire and by heavier coaling to run with fewer boilers.

In this matter of draft regulation, it is much better to have a

regulator that operates slowly than to have one so sensitive as to be opening and closing on a slight variation of pressure, thereby letting in an excess of air one minute, and then tightly closing, cutting off the air supply altogether which makes for another loss to follow by imperfect combustion.

If you have such a sensitive damper, it is not necessary to throw it out, just limit your range of damper opening, so that it does not shut tight or open to its fullest extent. The regulating damper should be as near the chimney as possible, and if it were placed at the top of the chimney, it would be better yet, as in times of closing, it would hold back that much more heat. As it operates now in many plants, when the damper is closed at the port, the brick lining or core begins to lose immediately its stored up heat and the chimney cools off, then when the demand for steam comes instead of an active chimney agent, it takes a bit of a while for it to recover its lost heat and give vigorous draft; meanwhile, the plant is held back in getting the supply of steam demanded. The condition becomes worse where the regulation is applied to dampers in the boiler uptakes, as during the time of cut off the flues have cooled as well as the chimney.

It will not be denied that any sort of a chimney gives some draft, in fact, a fair draft as practice is to-day, but I maintain that the average draft is not up to what it might be and should be, hence we are generally using too many boilers and firing at a disadvantage for the best economy. New boilers are purchased to get thinner fires or artificial draft frequently installed that would be unnecessary if the chimney were properly worked out in the beginning.

THEORETICAL CAPACITY AND PRESSURE TO A CHIMNEY 100 FEET HIGH.

1. Assumed height = 100 feet.
   Assumed area = 1 square foot.
   Assumed gases = 450 degrees Fahrenheit.
   Assumed outside air = 60 degrees Fahrenheit.

2. The first step is to ascertain how high the 100 foot column of air will balance a column of gas at 450 degrees Fahrenheit.

The density of a gas varies in direct proportion to its temperature from absolute zero (461° below 0° Fahrenheit).

$$60 + 461 : 450 + 461 :: 100 : x,$$
$$\text{or} \quad 521 : 911 :: 100 : 175$$

3. Velocity or fall will be the difference between 100 feet and 175 feet or 75 feet.

And velocity is expressed by the familiar formula

$$V = \sqrt{2gh}$$

Calling g, which is the acceleration due to gravity 32, this formula becomes

$$V = \sqrt{64h} = 8\sqrt{h} = 8\sqrt{75} = 8 \times 8.66 = 69.28.$$

That is, for each square foot of area there will be 69.28 cubic feet emptied per second.

4. The weight of chimney gases at 450 degrees has been determined to be 0.045 pounds per cubic foot, hence:

$$69.28 \times .045 = 3.1176 \text{ pounds per second.}$$

3.1176 x 3600 seconds per hour = 11,223 pounds gas per hour per one square foot of area.

We now have a practical, safe result to work with.

If we assume 84 pounds of gas per 1 boiler h.p. then $11{,}223 \div 84 = 133.6$ h.p. per square foot of chimney area.

1000 h.p. of boilers with stack only 100 feet high requires theoretically therefore only 7 square feet of area and if above 100 feet high, it would be of course less.

Now you can double this area in practice or triple it, but when some quadruple and quintuple this amount, it is time to halt as the increase adds nothing to the effectiveness but the reverse.

As to pressure:

A cubic foot of water weighs 62.37 pounds and one inch of this equals 5.2 pounds, so if we divide the pressure per square foot by this or multiply it by $\frac{1}{5.2} = 0.192$, we shall have the height of column of water which it will support in inches.

The weight per cubic foot of a gas at any temperature may be found, therefore, by dividing this constant product of the weight and absolute temperature by the given absolute temperature.

Air at 32° weighs 0.080728 pounds per cubic foot. Its absolute temperature is 493.2. The product of this weight and temperature is

$$0.080728 \times 493.2 = 39.8$$

So that to find the weight per cubic foot of air at any temperature it is necessary only to divide 39.8 by that temperature plus 461.2, *i.e.*, by the given absolute temperature and we can say, calling the density or weight per cubic foot D,

$$D = \frac{39.8}{t + 461.3} \text{ or } D = \frac{39.8}{T}.$$

The weight of a cubic foot of chimney gas, which is not simply heated air, but a mixture of nitrogen, carbonic acid gas, etc., would be about 0.084 of a

pound per cubic foot at 32° for perfect combustion of ordinary coal, and 24 pounds of air to the pound of fuel. Its weight per cubic foot or density at any other temperature would be

$$d = \frac{.084 \times 493.2}{t + 461.2} = \frac{41.43}{T}.$$

Density of air at 60 degrees = D = 0.0763
Density of gas at 450 degrees = d = 0.0454

.192 x 100 feet stack x (0.0763–0.0454) = 0.593 inches, practically 0.6 of an inch, and will be the same for all stacks 100 feet high when the gas and air temperatures are the same as the above, regardless of any difference in area or whether only one square foot or fifty.

ARTIFICIAL DRAFT.

So many favorable comments and demands were made for copies of my previous paper on natural draft which showed the wide-spread interest of intelligent students to secure tangible and more definite knowledge of that subject, that I am glad to have opportunity here to add some remarks and suggestions to the use of Artificial Draft as it is a subject of rapidly growing interest and importance, as natural draft is so varying in its action between different places—and in the same place—and in one hour with another, that no exact rules can be made in regard to it. Hence the broad empirical formulas for chimney sizes and the wide divergence in practice of heights and areas that are seen in use to handle similar amounts of boiler horsepower—being based on opinions and deductions more or less sound from the experience of their engineering advisers.

Utilization of forces in nature which are affected largely by the weather have an uncertainty of reliability—such as tidal power, wind-mills, water-falls, etc. When, therefore, the use of such a fluctuating force is made the sole reliance for the economical burning of fuel and with public service corporations to meet unfailingly the growing demands of their patrons—the engineering talent is found perplexedly attempting to formulate definite rules or regulations to constantly changing firing conditions, which at best can only be general, or practically to make the best use of whatever draft is available at the time, so what measure of success is attained thereby is, of course, to their credit.

The never-failing interest on the subject of natural draft and

the more general realization of its elusive quality to be confined within any certain formula, is making for greater study of the advantages of artificial draft for producing a definite positive draft pressure for the right volume that will be suited at all times to precise needs. Combustion being a chemical action which is an exact science, it is possible to make definite experiments of the requirements of any fuel for its complete combustion and then maintain the same in constant everyday practice very closely if given the operating facilities that will reliably supply the conditions determined by the laboratory and experimental investigations.

The generalities of this subject have been well stated by Mr. C. E. Roehl in a discussion before the American Street and Interurban Railway Engineering Association where he said:

"Capacity is fundamentally a matter of rate of firing. Firing rates vary widely, whereas efficiencies with a given grade of fuel do not; therefore, it follows that it is only necessary to get coal into a furnace and burn it to cause the rate of steaming to vary very nearly in proportion to the rate of firing. The practical response of the rate of steaming to the rate of firing follows logically from the modern recognition that with boiler equipment actually in service at the present day, the limitation of the heat transmitting ability of the metal of the heating surface is not approached.

"Higher steaming capacity usually reduces labor charges and inevitably reduces investment charges. It reduces the labor charges because, as a rule, more coal per man is being fired and more steam per pound of coal is being obtained. Investment charges are reduced because greater power is obtained per boiler. Maintenance charges increase, but the increase is practically confined to the furnace and, except in very special cases, while an offsetting factor, it is not a ruling one.

"Moderate increase of evaporating rate, 100 or 150 per cent., or perhaps more, must be brought about. Installation of very large capacity city turbines has forced this and in isolated instances a good deal has already been accomplished. There seems little reason to doubt that the best which has at present been accomplished will in a few years become standard practice."

Another statement on this subject from the *Electrical Engineer*, London, is worth attention:

"It is frequently quoted that with mechanical draft a smaller excess supply of air than that demanded by theory is required than with natural draft. In all probability this arises from the fact that natural draft pressures, are, as a rule, considerably lower than those mechanically produced, and fires are worked with less thickness with the former, so that such a thorough and uniform mixing of the coal and coal and air does not take place as with the great pressure and thicker fires of the latter."

Artificial draft may be either of two systems or a combination of both, namely, the Induced Draft, Forced Draft or Balanced Draft.

The Induced Draft or Suction Draft has all the advantages of the natural chimney draft, with the additional assurance of providing almost any positive required draft pressure that will be needed and where the plant is in its infancy, it is frequently better to use an inexpensive induced draft than to incur the investment charge for a huge chimney against future needs which are indefinite, perhaps to a remote period. While generally the cost of the induced draft is 75 to 80 per cent. less than an equivalent chimney capacity, its proportionate expense is not fixed, as the greater the chimney height, the less the induced draft equipments cost in proportion and if foundations are particularly expensive for the chimney the relative difference in cost becomes greater in favor of the induced. By using powerful fans the outlay for boiler installations can be reduced at least 25 per cent., and in one case the company I represent cut it by one-half with great success. This saving would fully offset the expense for the highest standard of mechanical draft equipment—or put another way, chimney cost would be saved altogether.

The maintenance of the induced draft is very small. If the plant is large enough to warrant using Corliss type engines, the operating expense can be maintained at less than one per cent. of the steam produced. In ordinary moderate sized plants the expense for operating a well designed equipment would never be more than double this, or 2 per cent., which would be an extreme to produce an extraordinary pressure. The equipment stands up well with small risk of break-down and by attaching a pulley which can be operated by a belt from the main drive or to an electric motor, the plant is insured against shut-down without the expense for duplicate apparatus.

Mr. Wm. R. Roney, in his valuable paper before the American Society of Mechanical Engineers, stated that the operating costs on several induced draft plants installed by his firm averaged about one-half of one per cent. of the horsepower of the total steam output. As his paper was written many years ago, I hardly believe he would claim that to-day, although it would be as easy to do it to-day by simply attempting to equal the ordinary natural draft applied to plenty of boilers with ample grate area, but it would take nearly all of one per cent. of the horsepower output to meet the draft demand for the concentrated development embodied in the present larger boiler units, for to obtain double the draft pressure of former times requires three times the amount of power applied to the fan. Calling it to-day then, one per cent. of the steam output, it is still a trifling cost commensurate with its results, while allowing all the exhaust from the fan engine to be utilized in heating feed water, the actual cost to produce the one per cent. of total horsepower output disappears almost altogether in fact, can well be ignored.

The writer has been much impressed with the growing demand for mechanical draft systems from manufacturers who may have only 200 horsepower or even less. Formerly such parties would rush to their boiler maker for additional boilers and build costly foundations in an enlarged building, and then struggle to work in the necessary new flues and pipe connections—all at expense for money and time in delays. Now, an inexpensive fan makes their present plant meet their growing increase and by further supplementing the boiler heating surface with Economizer tubes, the steam output may be even doubled with no excessive heat waste up stack—all accomplished rapidly at moderate cost and within the limits of the present building. The boiler makers themselves are lending to the growth of artificial draft because owing to the competition among themselves, they know they can offer the purchaser a better trade per horsepower cost in the larger single units, which puts the buyer, however, to the expense of building a greatly higher chimney to obtain the expected rating or purchase the low-priced induced draft apparatus when he can then accomplish the rating with ease and even more.

Induced draft fans are usually provided with water-cooled bearings, to protect the babbitt from melting down, but I have

known where induced draft fans have been used for eighteen years without any such water, in fact, the bearings probably can be kept sufficiently cool by small openings in the fan case around the bearing so that some cold air will always be drawn over same. This had better not be attempted with direct connected engine sets, as it would draw more or less gritty dust over the engine as well, which would work into its bearings and cross-head. A half inch water pipe, however, will furnish all the water generally necessary to the largest size of induced draft fan. In my practice, I regularly install such cooling system as it is a very simple safeguard to adopt.

As a general rule, horizontal engines are preferred to very large fans if foundations can be had on the ground, but in elevated positions, the vertical type is preferred to avoid lateral vibrations.

The Forced Draft blows the air under the grates and the cost of operation is the same as for the induced draft, because, although it has a smaller fan, the weight of air to be moved in a given time is the same as the induced draft would have to handle if used at the other end.

There are different methods of regulating both forced and induced draft sets. Frequently an actuator is used to operate by means of crank levers, for regulating the fan speed by moving the governor. In my practice, I get precisely the same effect by simply inserting a pressure regulator in the steam supply to the engine.

Where forced draft is used in connection with a chimney draft which already is controlled at its port by an automatic damper regulator, another wire can be connected from it to operate a simple balanced valve in the steam supply to the forced draft so both the chimney damper and forced draft work in unison—such system is called *Balanced Draft.*

Whether Induced or Forced Draft is installed the engineer should study the operation of his fan engine and set his governor and cutoffs to suit the best uniform speed, because as the requirements are put up to the fan builders to meet the most maximum conditions contemplated, an ample sized engine with suitably adjusted cutoffs will be furnished to give ability to meet those extreme demands and too often the operator relies solely upon his regulator to take care of his load adjustment, with the result that the movement is constantly in motion, with the fan at one

moment working at its maximum and whooping the fires up so that the pressure gains for some time after the fan has slowed up. That the engineer should therefore make any new engine adjustment that may be needed to suit his normal conditions, should not require further argument. It would make for a marked improvement in economy and enable those in charge of the coaling to fire better under the more uniform draft conditions.

Speaking for New England, there are probably 10 Forced Draft fan systems installed to one of Induced Draft, indeed counting the various steam jet systems with same, I judge there are 50 forced fires to one artificial suction draft system. This is natural on account of the ease of installing the former, and its lower cost. Then, too, forced draft is better adapted for burning the fine grades of anthracite or buckwheat which pack on the grate so densely as to make too serious a demand for draft from any suction fan to be practical, whereas a strong underneath blast will keep the coal lifted and keep the particles in motion so the air is thoroughly mixed, producing a good fire with little smoke.

If the exhaust steam from the fan engine is blown into the air duct it will prevent clinker mass from forming and fusing on the grates. This has become quite a common practice and proves generally beneficial.

The forced draft usually makes a hot, dirty boiler room and frequently makes more arduous conditions of labor, as the heat tends to fly out upon them whenever doors are open. Then, too, the air blast seeks the weakest place of resistance in the fire and through such places produces holes letting in cold air to no good purpose. I think, however, there are considerable possibilities of economy with this system where firemen of superior intelligence are employed, as with carefully run fires, a thorough combustion can be obtained and the heat therefrom will be forced into effective contact with all parts of the heating surfaces.

The most common fallacy in regard to this use of forced draft is that it is a quick, inexpensive remedy where the present draft is inadequate. This proves true in some cases and in others, it will make for worse conditions than before.

The situations where it will benefit, speaking now as a draft remedy, will be where areas through flues and chimney are ample, although the height of the stack is too short to produce the necessary pulling force.

Whereas on the other hand, the case being one where the height and areas are both inadequate or outgrown, then the introduction of forced draft to such, requires a fierce blast to overcome the resistance ahead of the gases to reach the atmosphere and makes for such force against the boiler fronts as to become a source of danger to the men every time the doors are opened for coaling, also such a draft condition is injurious to the settings, as well as the fronts.

Forced draft, then, requires either a good draft at the other end, or paradoxically, no draft at all, but a short spacious path to out of doors. If any of you have forced draft in your plants which works too strenuously against the fronts and it is impossible to keep up steam with a lower air pressure, then you want to adopt the suggestions of providing easy vent after leaving boilers or improve chimney draft or adding the positive induced draft. But there is another remedy which might be worth trying if your boilers are of Water Tube Type, and that is, to remove the bafflings; your heat—as shown by the conditions of pressure around the front—is going to be just as efficiently brought in contact with the heating surfaces without assistance of the boiler bafflings in such cases.

Abroad intensive firing is being adopted on larger scales and in the development to achieve the highest results in some of the great electrical and industrial stations they are equipping their plants with huge thermal storage tanks in addition to their Economizers. These things are bound to follow in this country as progessive boiler builders realize that whatever helps the economical production of steam is to their advantage in keeping pace with their wide-awake competitors who are scientifically improving the efficiency of gas producers.

The prime movers of the plant have heretofore had the first place in attraction for study and development and thousands of dollars are spent to secure only a small economy which may be offset in the adjoining room by the firemen unnoticed. However, just as the public has had a surfeit of the moving signs on the Great White Way, so is coming the day when the owner will walk his visitor past the wonderful turbines into his boiler room and there throw out his chest with pride at its display of cleanliness, and its well-studied features to secure all the heat possible from the fuel by its most complete utilization.

MODERN COMMERCIAL FOOD MANUFACTURE.*

BY

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THE subject of food manufacture, whether it involves commercial or domestic food preparation, is at best, a homely and prosaic one—yet, withal, in itself, of interest, because of its large importance.

The relative importance to a nation of its food supply, in comparison with other essentials, is perhaps seldom adequately realized.

The food industry of the world is the world's greatest industry. From the tillers of the soil, and those who go down to the sea for its treasures, to the servitors at our tables, the number of those who are in some manner engaged in supplying the food demands of the human family, is greater probably than required for any other industry, as great possibly as for all others—vast almost beyond computation.

Food, shelter, raiment are the three great fundamental requirements of human life, and of these three food has been, from the beginning of time, the first consideration. To appease hunger was the problem of primitive man and his greatest stimulus to effort. His first and chief demand upon the earth and the elements about him was for food; and the first, last and most particular requirement of his civilized brother to-day still is that food be supplied him. This is the great common ground on which stand both savage and philosopher. Shelter and raiment were to aboriginal man of secondary importance—as they are also really of secondary importance to-day. Thus, being the one great essential to life itself, the struggle for food has probably been in all ages the influence that has contributed most to the survival of the fittest—the mainspring that has stimulated the action of the world.

It is not by any means an unwarranted assumption that the effort man has been compelled to put forth by this necessity has

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constituted the stimulus of human advancement—the responsible, underlying cause of our modern civilization.

For it is easily conceivable that if the incentive of hunger had not been given to the human race, the learning and luxury of modern times might have been much less evident, or that, if the daily demand of nature for food should miraculously cease, mankind would speedily retrograde.

If then, so much of our lives and so much of man's ambition are bound up in the great universal subject of "What to Eat and How to Get It," we surely do wisely to consider well what manner of food we are getting in return for life's struggle. Whether it is pure, clean and wholesome; whether it is calculated to give us the sustenance and strength, the health and prolongation of life that we have a right to expect; or whether it is sometimes so far a mixture of bad with the good, that almost literally we are given, when we ask for bread, a stone.

Food may be defined as consisting of those substances which are capable of sustaining the animal organism in a state of health and as that which makes possible the continuing existence of all forms of life.

There is a quality inherent in all food which, under natural conditions, renders it changeable and perishable. The atmosphere which surrounds us, coming as it does, in contact with every substance, unless removed or excluded as when in a vacuum, contains germs which are always active and whose mission is the destruction of all organic matter. These are the active causes of the change known as decomposition. To prevent such change, various means have had to be devised for keeping food from putrefaction and in a wholesome condition; drying, salting, chilling, heating, canning, coating with gelatin or fat for the exclusion of air, and the use of chemicals.

The practice of food preserving dates back to a prehistoric period. It is traditional, rather than historic, that man in the early ages, by a simple drying process, was afforded a means by which the accumulation of bountiful years and the surplusses of seasons of plenty could be carried over to provide sustenance through lean seasons and years of famine.

In hot climates, the heat of the sun was probably at first the sole preserving agent; while in colder latitudes where shelter and artificial heat were needed, we may well believe that the dis-

covery of the preservative quality of wood smoke and the taste for smoked meats and fish closely followed the discovery of fire itself and came about through the suspension of the family larder from the roof of the family hut, where the food became impregnated with the rising vapors from burning wood and peat.

It is thought that the first discovery of the preservative use of salt was quite as accidental and due to the finding of meat carcasses in a good state of preservation, embedded in the incrustations of saline deserts.

Meat and fish, as well as fruits and vegetables, have also been kept for certain periods by sugar alone, but in the light of later day experience, it is known that few articles of prepared food in common use can be kept *when exposed to air,* by any single preservative substance or process.

It is also known that the *exclusion* of air is not *alone* sufficient to preserve changeable food substances successfully, because foods cannot be so collected as to exclude organisms; and the yeasts, moulds and bacteria which have been carried to their exposed surfaces in the dust of the air will develop fermentative and putrefactive changes, unless in addition to hermetic sealing the food is sterilized by sufficient heat.

Modern food preserving in its broader adaptation may be said to have had its origin in the discovery by the Frenchman, Appert, in 1804, that an article of food first heated, then hermetically sealed and sterilized, would keep practically as long as the seal was intact, without the use of chemical assistance.

One year later, De Heine, then in England, patented a process by which he claimed that food could be preserved by completely exhausting the air with an air-pump. All attempts at this, however, seem to have been unsuccessful, until a process discovered by one Wertheimer in 1839 came to be used. This provided that the food to be preserved should be placed in tin or metal cans, the interstices being filled with water, juices or other fluid, and the lid to be securely sealed. The cans were then set in water and boiled, the air being expelled through small holes pierced in the lids. When the food was sufficiently cooked and the air entirely driven out, the holes were filled with solder, completing the process. Food thus treated would remain in a perfect state almost indefinitely. No very great improvement, other than the elimination of solder in the sealing of tin containers, has

since been made upon that method and no change at all in principle. And, while the *theory* of these men differed from that accepted by modern science, the same *means* are used and the same results obtained as to-day; the process here described being used in all large canning factories in America, as well as the countries abroad, and in principle at least, practised in every household in which fruits and vegetables are preserved.

Although Appert's discovery was made more than one hundred years ago, it is only within comparatively recent years that its commercial value has been so fully appreciated as to cause its extensive employment in a commercial way on the American Continent, at least.

The early influence of the discovery was quite marked, however, in the home kitchens of our thrifty forebears in the New England and Middle States, where, with ever increasing skill in cookery as generation followed generation, a high degree of success came to be attained in the preservation of the fresh fruits and vegetables of the harvest season for winter use.

The products of these home kitchens were many and varied. Their appetizing qualities were due to the excellence and freshness of the material employed; their keeping qualities were in proportion to the skill and exactness of their preparation and the cleanliness with which it was surrounded. No artificial chemical anti-ferments were known to our grandmothers and none were required in their preserving work.

"Preserves" was then a word to conjure with. It stood for the sole delicacies of a large proportion of the whole nation. It was the embodiment of feasting and good cheer. It lent an especial significance to holiday dinners and "company" suppers. It calls up to-day, visions of mothers and grandmothers, busy as bees in roomy kitchens, their faces aglow with the heat of their work and their pride therein; surrounded by pans and baskets of luscious and toothsome products of farm and orchard, and by the most tantalizing odors that ever assailed the nostrils of unappeasable youth. It brings to us visions of rows of enticing jars and bottles on high, forbidden pantry shelves; of moments of fond maternal yielding to insistent and flattering persuasion, and exciting conjecture as to what delicious jam or preserves would be forthcoming when the minister suddenly appeared at supper time.

But, with the passing of time, the old fashioned manner of living changed. The increase of wealth increased enormously the demand for luxury in living, while the gathering of the population in cities brought about a congestion which made the former method of supplying the food demand wholly inadequate, and it was with the coming of these conditions that the manufacturer of prepared foods entered upon the scene, to become one of the great factors in the nation's progress.

And it may be said, and I wish to emphasize this in passing, the principles and practices of these old-time home kitchens furnish the best traditions that govern the preserving industry of to-day. It is as true now as then, that the best results in product can only come through the employment of good material, the maintenance of a high degree of sanitation and the application of conscientious skill; and this, regardless of whether the work is performed in the home or the great commercial kitchen, but the demand upon the modern commercial kitchen in the way of almost infinite variety, makes these requisites to a high degree of perfection, doubly essential.

While the canning trade—that branch of food preparation which shows the most remarkable expansion—had its origin, as has been stated, more than a hundred years ago, it was not until a comparatively recent date that the canning business assumed the dignity of an industry and entered upon the era of expansion that has carried it to its present vast proportions, amounting, it is estimated, to an output of more than sixty millions of dozens of the three leading vegetables—tomatoes, peas, and corn—during the last season; not to mention the other millions of dozens of meats, vegetables, fruits, and miscellaneous foods.

I shall not indulge in statistics, because figures in this connection are too bewildering to convey a comprehensive understanding. To speak of a quantity of ten millions of bottles or twenty-five millions of cans is simple enough as a mere statement, but the actual quantity itself, resolved into an existing fact, is inconceivable to the average mind not trained to think in millions.

In the early days of the commercial food preserving industry, the manufacturer confined himself to a very few articles which, although honestly enough made, were more or less indifferent in quality. With improved facilities, however, his skill in cookery

gradually increased and with it the volume of his business; a development through which the food resources of the world have been wonderfully augmented, affecting not only our own methods of living, but changing the restricted diet of the Polar Regions and the Tropics to the bounty of the Temperate Zone.

For, in this progressive age, it was inevitable that this question should arise—as arise it did—"Was it not possible to duplicate, nay, to improve upon the time and man honored products of countless kitchens and skilful housewives; and to place them on the general market within the reach of all who wished to taste their delights?" It was possible and it was done. Prepared foods have grown in number until there is now estimated to be about five hundred, and through this growth the laboring man of to-day may, and does enjoy food luxuries which, fifty years ago, the rich could hardly obtain.

In the meantime, the business offered an inviting field for the not over-scrupulous manufacturer. It was found that inferiority of raw material, imitation and adulteration, artistically colored and thoroughly embalmed with artificial preservatives, could be so concealed beneath a veneer of attractive appearance and fanciful labelling, as to obtain a ready and profitable market; and, as evil always seems to be endowed with more vitality and spreads more rapidly than good, the evil of adulteration and inferior food preparation swept over the country like a prairie. fire. That peculiar trait of the American people which is called "The bargain counter mania," afforded the unscrupulous manufacturer an outlet for his lower priced product; cheapness became the goal of his ambition and this ambition was realized and the goal reached by placing upon the market, not only products which contained not a single drop of the ingredients of which they were supposed to be made, but products having no other claim to merit than to pay a profit to the manufacturer who produced and the dealer who sold them.

Such practices could not long exist, however, in a civilized community without attracting the attention of scientific men interested in the public health and welfare, and, out of the discoveries made by these men, came the agitation which finally led to the enactment of better State and National Laws for the protection of the people in this vital matter.

That the National Law has brought about a revolution in some directions, no one will deny. There is certainly less cheapening adulteration going on—less misrepresentation and deception; but there still remain many abuses to be corrected, chiefest among these, I believe, the continued tolerance, by compliant authorities charged with the administration of the law, of artificial preservatives.

The rapid growth of the preserving business in its early stages attracted much capital without corresponding experience, and in such cases, for the most part, business disaster was only averted by the extensive employment, in nearly everything produced, of chemical anti-ferments, which served as a protection against all the mistakes of cooking, sealing, and sterilization, and obviated entirely the necessity of proper sanitation either in methods or surroundings.

The first objection to their use, however, and, I believe the most glaring abuse that exists to-day, lies in their employment for the purpose of preserving partly spoiled and ill-cared for vegetables and fruits.

The principal substance that is used for the artificial preservation of vegetable and fruit products, as well as for meats and fish in some cases, is the drug, Benzoate of Soda—which, in its least objectionable form, is a tasteless and odorless derivative of coal-tar.

It is not my purpose to discuss here the extent to which the substance, Sodium Benzoate, itself, may be harmful. That is a scientific question, the discussion of which I am willing to leave to scientific men, confining myself rather to a few brief words concerning its possible significance in food products.

But, before proceeding to this phase of the artificial preservative question, I would like to call attention to the fact that the weight of scientific evidence, especially on the part of the medical profession, is strongly opposed to it and to suggest that if there is a doubt about the amount of injury that it causes, the people and not the manufacturing interests who desire to continue its use as a means of securing a greater pecuniary profit should have the benefit of that doubt.

As I have said, however, it is rather the possible significance of artificial preservatives in modern food manufacture, than their

own injurious nature, that I wish to touch upon. You may call it, if you please, "The Moral Side of the Artificial Preservative Question."

Let me state at the outset that every product of fruits and vegetables with which I am familiar can be successfully made in a commercial way, without artificial preservatives. This is evidenced, beyond dispute, by the fact that the entire product of at least twenty-five, and probably more, leading American food preservers is entirely free from these substances.

Why, then, should any one wish to continue their use? Commercial cupidity, my friends, yields very grudgingly to attempted reform. There is cannery waste to be worked up profitably into ketchups and soups—skins, cores, and decayed parts of tomatoes, cooked up and thrown into barrels to be shipped about the country for use as wanted. There are always job lots of spoiled or partly spoiled fruits and other similar materials lying about in the season that can be picked up cheaply. To say nothing of the expense attending its proper disposal, it is hard to send such material to the sewer when profit can be gained from it by sufficiently dosing it with a chemical preservative to protect it from putrid fermentation, and then disguising its taint with spices and flavors until it really becomes quite presentable and in some degree acceptable to those who do not discriminate very closely in favor of quality and who are only slowly learning the signficance of the legend on the outside of a package: "Preserved with $^1/_{10}$ of 1 per cent. of Benzoate of Soda."

While the demand of the reactionary manufacturer for the continued tolerance of some kind of an artificial preservative is based upon several reasons, the principal pressure in its favor comes from users of tomato waste which has a commercial importance not generally understood.

Tomatoes are probably more extensively canned than all other summer vegetables put together—and all the canning is done in a period of six to eight weeks, under high pressure.

Tomatoes are also more extensively used in soups, condiments, sauces, etc. than any other fruit or vegetable—the consumption of tomato ketchup alone running into many millions of dozens annually.

In canning tomatoes, the canner's first and best attention is naturally to his principal product, and it may be said that it is

generally a most worthy product; but there is a great amount of waste—skins, cores, and decayed tomatoes—which there is neither time nor inclination to care for and which falls under foot disregarded as it accumulates.

Hundreds of thousands of barrels of this refuse are made in a season. It is pulped and put into the barrels under conditions that would better be left to the imagination than described, and then chemically "preserved" against actual putridity. It is safe to say that no one would ever again desire to eat any benzoated article after once seeing this material and its treatment.

This tomato refuse is sold at about $1.00 to $3.00 per barrel, to be made into tomato ketchup, soup, baked bean sauce, etc., which are eventually labelled as made of fresh, ripe tomatoes, and which carry only one protection to the consumer namely, a statement of the presence of the preservative on every label, which is put there under one of the occasional beneficent food regulations of the Agricultural Department at Washington, but it is always printed as small and obscurely as possible. Thus the consumers' only protection is to read all food labels carefully, including the fine print.

Such goods are extremely profitable, being sold at only a trifle less than goods made of the best raw materials, and it is really around the tomato waste industry that has rallied most of the effort for the nullification of the Pure Food Provisions of the National Food and Drugs Act.

A term much employed by the pro-preservative interests in their defense is "concealed inferiority" and elaborate arguments are set up to show that the addition of a chemical preservative to rotten tomatoes or fruit, for instance, changes neither the odor nor flavor of the material—while, as our friends proceed to show us, vinegar, sugar, salt, and spices will disguise unpleasant odors and flavors; and then they proceed to vigorously attack the use of the time-honored condimental preservatives, but there is a maxim as ancient as the time of Democritus which reads: "Whatever pleases the palate nourishes." Modern science has proven the truth of this maxim and has given us acceptable reason why condiments are necessary; why they are used by all castes, races, and civilizations. Acting principally upon the nervous system through the sense of smell, condiments stimulate the flow of both the saliva and the gastric juices. They materially aid

digestion, and the familiar phrase, "to make the mouth water," states a physiological fact.

And, unfortunately for the line of argument of the reactionaries, nobody contends or ever has contended, that Benzoate of Soda "conceals inferiority." Being tasteless and odorless, it has no more effect in that direction than would have so much cornstarch or wheaten flour. The expression "concealed inferiority" is simply one coined by the friends of chemical preservatives as a premise upon which to build false argument.

Artificial preservatives do not conceal inferiority, but they do permit and encourage disguised inferiority and the grossest fraud.

With artificial preservatives permitted, commercial cupidity is further aided, not only by the elimination of all need for factory sanitation and care in cooking, but as much water may be left in, to further cheapen the product, as suits the convenience of its maker. Also, bottles and other containers need not be washed and sterilization becomes a useless expense.

I have no hesitation in saying that the principal use of Benzoate of Soda and like substances in modern food manufacture to-day is either to permit the use of a lower grade of material, or carelessness in process. Its tendency is to lower quality in some direction all the time and to invite actually unwholesome practices, and the question of whether we are to have cheapness in our foods at the expense of quality and wholesomeness is as much alive to-day as it was before a Food Law was placed on the Statute Books.

We are turning the light into the obscure and unsanitary bake shop. We have cleaned up the meat packing establishments and deprived them of their artificial preservatives. It is high time that better attention should be given to the vegetable and fruit preserving industries, and that by the withdrawal of the temptation furnished by this mischievous preservative substance, permitted not by law but in spite of the law, we can come to feel that we are secure in eating only those things which we would readily eat if we saw them made and saw the material entering into their composition.

The modern manufacture of foods that are pure in the best and strictest sense, however, the really modern, up-to-date factory is not a place of gloom, dirt or mystery. And the underlying

purpose of the progressive manufacturer is to give the public the choicest products so prepared and packed as to offer at a reasonable price, the highest attainable degree of quality, purity, and cleanliness.

The chief reliance of the better class of food preservers is sterilization. In the preparation of foods by canning, preserving, etc., the most essential things in the processes are the sterilization not only of the food, but of all utensils and the careful sealing of the sterilized food to *exclude* all germs, because, as has been shown, both air and water contain bacteria and yeasts and may contain mould spores; and both foods and all utensils used in the process of preserving foods, are liable to be contaminated by these organisms. For this reason the appliances, as well as the food, must be sterilized until all life and sources of life in and about them have been destroyed.

Most of the appliances of the modern food factory are automatic. The direct personal contact with foods by human hands is discouraged and reduced to a minimum; and, where unavoidable, it is a modern practice that all who are engaged in work requiring this, shall have their hands frequently inspected and at brief intervals subjected to a thorough manicuring service.

Where kettles are used, the material is usually of burnished copper and they are provided with steam jackets which permit the application of high degrees of heat without scorching and of perfect, instant regulation. Conveying pipes for liquids are usually silver lined to prevent the action upon them of fruit and vegetable acids and the sterilizing appliances, both for containers before putting them into use and after filling, are the best that scientific skill can devise.

The doors of such great modern commercial food kitchens are nearly always wide open to visitors, to permit the freest possible public inspection of both materials and methods.

Those who cherish the belief that the kitchen of some vigilant and ultra-fastidious New England relative embodies the highest degree of spotlessness possible to human achievement, freely admit, after seeing both, that in the modern commercial kitchen, even she, with all the honor that is her due, has been outdone and surpassed.

In the invitation extended to me it was suggested that I present some illustrations—a suggestion which I accepted some-

what hesitatingly, because the only readily obtainable views for use in this manner would of necessity be from the establishment with which I am personally connected. However, they are for the most part only typical of what exists in many other similar establishments.

Fifty-four lantern slides were then shown illustrating the growing, gathering, and preserving of vegetables, the harvesting of olives and the preparation of olive oil, and the process of preserving the various fruits from the fresh product to the sealed can.

The speaker closed with the following remarks:

Thus you will have seen that the modern commercial preserving idea is, in all essential respects, that of the housewife of long ago. The fine, old, home-made idea. The housewife selected her fruits and vegetables with anxious care, choosing only the best, as befitted so important an occasion as the preserving season. In her snowy kitchen, she prepared them and put them up according to time-honored recipes. This is the modern, up-to-date preserver's idea precisely, in its primitive fundamentals, but it is improved upon vastly. He goes forth into scores and hundreds of gardens and orchards, and he too, selects the best and discards all else. He, too, works in snowy kitchens, but in kitchens where cleanliness is enhanced by sanitary precautions and appliances beyond the housewife's reach; and the recipes upon which his work is conducted are simply the good, old-fashioned, housewifely kind, but improved and refined by the best work and thought and experiment that capital can supply or painstaking care obtain.

Hypochlorite Treatment of the Omaha Water Supply. JAY CRAVEN. (*Eng. Record*, lxiii, 128.)—This article shows the efficacy of settlement followed by hypochlorite treatment in removing bacteria from the water supply. The water is first pumped into sedimentation tanks and allowed to settle. When the water is very turbid, aluminum sulphate is used as a coagulant. This sedimentation reduces the bacteria 97.4 per cent. The settled water is then treated with hypochlorite, in the proportion of 0.3 parts per million of available chlorine, ranging to 0.35 or 0.4 parts per million according to conditions, which gives a further reduction 93.3 per cent. in the bacteria in the settled water, making the total reduction in bacteria 99.83 per cent.

NOTES ON THE DESIGN OF CENTRIFUGAL PUMPS.

BY

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A CONSIDERABLE degree of uncertainty and confusion of ideas appears to exist in the design of impellers for a given discharge. The average designer in determining the width of the impeller *b*, Fig. 1 is generally guided by the nearest available precedent with a result often at variance with expectations, and it it is not at all uncommon to find pumps yielding a discharge 30 per cent. or 40 per cent. "short" of the specified capacity.

Although many articles have been written devoted to the subject, none of them gives the designer any immediate help in solving his problem by presenting a reliable theory in a concise form. The problem is generally as follows: *Given the total*

FIG. 1

head, the speed and the discharge, to find the proper diameter and the width of the impeller.

Practice has shown, that, regardless of other requirements (such as the flatness of the efficiency curve, the variation in the shape of the horsepower curve according to a certain prescribed law, etc.) the discharge is subject to certain definite rules that can be easily understood and applied, viz.:

1. *The ratio of the radical velocity, Ur, to the peripheral velocity, U, for a given type of pump working under favorable conditions is a constant, X, so that* $Ur \div U = X$ *Fig. 1.*

2. *By plotting efficiency curves for various speeds in the discharge-efficiency diagram, it will be noticed that the points of maximum efficiency of each curve fall nearly on a straight line, hence the constant, X, varies but little with the speed.*

3. *The use of "radial velocity" alone as a means of determining the width of the impeller will always lead to error. A correct value of the radial velocity cannot be prescribed and is seldom correctly assumed.*

The latter method is apparently customary with designers and, it is said that nine pump builders out of ten include in their quotations the cost of an extra impeller, it being quite out of the question to "guess" at the correct shape without a trial.

The general tendency to make the width of the impeller excessive is scarcely justified by the results of such practice. It may increase the *pressure* but only with a considerable loss of efficiency. The fault mainly lies in the suction ends of the blades. Many an impeller in which the suction tips of the blades were very carelessly designed would not admit the desired amount of water into the impeller. A well-known pump designer has stated that he advocates radial blades at the entrance, this shape being "just as good as any," a procedure scarcely in keeping with fundamental laws of dynamics.

Assuming, however, that the suction elements of the blades are correctly designed, the various values of X as given by both theory and practice may be considered by an examination of the following examples:

Ex. 1. Impeller approximately 20 inches in diameter, speed 870 R.P.M. Efficiency *excellent*. Angle of the blade with tangent at discharge 48 degrees. $X = 14$ per cent.

Ex. 2. From M. R. Tison's article in *Revue de Mécanique*, Oct. 31, 1909, X appears to be 17.4 per cent. for blades inclined at 45 degrees to the tangent and 19 per cent. for blades discharging radially.

Ex. 3. Electrically driven pump of 30,000,000 gallons daily capacity. Diameter of impeller 37⅜ inches, width 5⅞ inches, efficiency *excellent*. X approximately 12 per cent.

Ex. 4. For roughly designed common pumps, X is often 10 per cent. to 12 per cent. For marine work, bilge pumps, etc., from various pocketbooks, X appears to be much lower, about 6 per cent. to 8 per cent. A higher value would undoubtedly increase the efficiency.

Ex. 5. Mr. Charles H. Innes in his book on centrifugal pumps, in comparing the results of his theory with Prof. Unwin's experiments, uses the formula U (radial velocity) $= \frac{1}{4}\sqrt{2gH}$ and, since the peripheral velocity for blade angles of about 30 degrees is close to $\sqrt{2gH}$, the ratio X appears to be about 25 per cent.

Ex. 6. In Prof. Rateau's high speed pump, the impeller is 3⅛ inches in diameter, width ¼ inch, speed 18,000 R.P.M., capacity 190 G.P.M. against 863 feet head. Efficiency, *good*. X about 7.4 per cent. These proportions

may be correct for so high a speed and so small an impeller, but not for lower speeds.

Ex. 7. Single-stage pump. Impeller 8 inches in diameter. $X = 8\frac{1}{2}$ per cent. Efficiency *rather poor.*

Ex. 8. Multi-stage pump. Impeller 24 inches in diameter. Speed 870 R.P.M. Capacity 1950 G.P.M. $X = 8\frac{1}{2}$ per cent. Efficiency, *rather poor.*

Ex. 9. Multi-stage pump. Impeller 31 inches in diameter. Capacity 3000 G.P.M. $X =$ a little over 11 per cent. Efficiency *good.*

Ex. 10. Single-stage pump. Impeller 14 inches in diameter. $X = 12.2$ per cent. Efficiency *good.*

Ex. 11. From experiments made at the University of Wisconsin (Madison, 1909) it appears that the best efficiencies were obtained at $X = 14$ per cent.

Ex. 12. Single-stage pump. Impeller 18 inches in diameter, 1184 R.P.M. $X = 14.2$ per cent. Efficiency good.

Ex. 13. From Dr. Grünebaum's book on pumps (Berlin, 1905) for radial blades, X appears to be 23 per cent.; for blades inclined at 31 degrees to the tangent, $X = 21.5$ per cent.

Ex. 14. From Prof. Boulvin's "Cours de Mécanique appliquee aux Machines" 7e fasc., p. 122 (Paris, 1897) $b_1 r_1 = \frac{Q}{2\pi} \frac{1}{\sqrt{\sin\gamma(1-\sin\gamma)}} \frac{1}{\sqrt{gH}}$ where b_1 is the width and r_1 the radius of the impeller (all in metres), Q is the capacity in cubic metres per second and γ is the angle of the blade with the tangent at the discharge, so that for discharge angles near 30 degrees and peripheral speeds approximately $= \sqrt{2gH}$, the ratio X will be found to be about 35 per cent. This is rather high. In fact all theoretical values of X seem to be much higher than the results of good practice.

Ex. 15. Prof. Church's book on "Hydraulic Motors" (1905, p. 177–178) does not give any formula for X but it can easily be derived by elimination of Un from equations 6 and 20. The result is $X = \frac{Vn}{Un} = (1 - \sin\delta)\tan\delta$. Thus for 12 degrees, $X = 16.8$ per cent.; for 30 degrees, $X = 29$ per cent.; for 45 degrees, $X = 30$ per cent.

Ex. 16. From the two examples given by Dr. Lorenz (*Z. ges. Turbinenwesen*, July, 1906) (*a*) Impeller 15¾ inches in diameter, speed 620 R.P.M., angle of blade with tangent 56 degrees; $\frac{2gH}{U^2} = 1.28$; $X = 36.3$ per cent. (*b*) Impeller 15¾ inches in diameter, speed 1000 R.P.M., angle of blade with tangent 151.5 degrees (curved forward).

Mr. Hanocq, of the University of Liege, in his most remarkable paper on centrifugal pumps (*Revue Universelle des Mines et de la Métallurgie*, March and June, 1909) gives several curves showing the dependence of the efficiency upon the value of X. One of his examples has been worked out for a discharge angle of 30 degrees and a suction angle of 35 degrees.

The writer has worked out a similar example for a 12-inch impeller having a discharge angle of 30 degrees and a suction angle of 16 degrees 20 min. The results are plotted in Fig. 2. The curve C gives the ratios $\frac{2gH}{u^2}$, u being the peripheral velocity and the curve R represents the theoretical hydraulic efficiency. These curves have been plotted for a pump having a *properly*

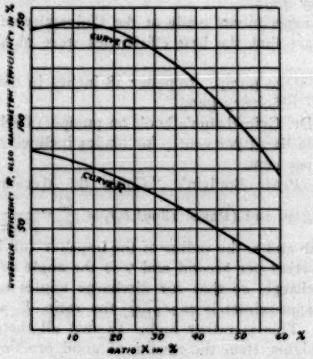

FIG 2

designed *diffuser*. For centrifugal pumps without diffusers, the curves would be entirely different.

The following conclusions may be then drawn: *There is no advantage in excessive width of impeller. Great care must be exercised in designing the suction elements of the blades. High speeds are consistent with good efficiency. The best values of X lie between the narrow limits of 12 per cent. to 15 per cent.*

INTRODUCTION TO CERTAIN FUNDAMENTAL PRINCIPLES OF MODERN PHYSICS.

BY

PROF. NERNST.

(Translated from the *Revue scientifique*, by W. J. Williams, F.I.C.)

EXPERIMENT AND GENERALIZATION BY HYPOTHESIS.

We can assign as the immediate and common aim both of physics and chemistry, the furnishing, in the greatest possible number of cases, of as complete and as simple an answer as possible to this question: Given, the operation of a system (of finite dimensions) what phenomena will be produced, and what will be the condition of the system at a definite period? To solve this problem, it seems to us indispensable to first realize the system, the future of which we wish to learn, and to study its history. The success of this attempt will depend on the ability of the observer, and on the means at his disposal, and this success will increase with the progress of experimental skill.

But the infinite variety of interesting systems which nature presents, and further, the immense labor which must be expended for a fruitful exploration (for it is not alone a single system undergoing transformation) would be enough to discourage the physicist, and make him recoil before a systematic study of the phenomena of nature, if we could not add to the ideas immediately apparent to the senses, other ideas conveyed by a valuable auxiliary. This auxiliary is to place the theoretical value on the experiments made on several systems, and consists in referring to a second system, by analogous reasoning, the observations made on the first system. If we have studied the phenomenon of the fall of a heavy body on one point of the earth's surface, we can refer some of the facts observed directly to other systems, *e.g.*, to the fall of a heavy body at another point of the earth's surface. The skilled glance of the physicist discovers and recognizes whatever there is in common in phenomena of quite different appearance, and his success is so much the more brilliant, the greater these differences appear.

The application of the observations made in one case to

another case, cannot be done without some uncertainty; but, by repeated verification experiments, it acquires a greater and greater probability, until it finally reaches the rank of an *empirical natural law.* For example, the discovery of such a law as that which enables us to calculate the specific heats of solid combinations by the help of certain numerical coefficients, the atomic heats of the elements, is an undoubted advance; so much the greater because this law includes many experimental facts, and has led to the foreseeing of others.

The history of the physical sciences teaches us that we can discover a new natural law by two essentially different methods, one of which may be called the empirical method and the other the theoretical. In the first method one endeavors, by experiments directed to that end, to collect a number of observations, expressible mathematically as far as possible, on the phenomena between which a relationship is suspected, and then to compare the results obtained. In this way it was discovered that there were certain relations between the properties of the elements and their atomic weights. On the other hand, the second method leads by logical ideas on the nature of the phenomena and a purely speculative activity, to a new conception, the correctness of which should be verified by experiment. In this way the law of chemical mass-action was found by kinetic considerations on the combination and dissociation of bodies which react on one another.

Of the two methods the first can be followed in all cases, and it always leads to certain results, although, it is true, only after very exacting work. As for the value of a natural law thus obtained, it is chiefly the extent of its application that gives the measure of its importance; and the consideration accorded to it should be so much the greater, the more numerous and the more varied are the phenomena to which it applies. Thus the principles of thermodynamics furnish us with the most brilliant example of the empirical discovery of a natural law, for they apply to all the phenomena of nature, and should always be taken into consideration in all scientific researches. On the other hand, such a law, whose domain is so vast, is much more difficult to understand, and demands much more skill in handling it, the more general it is in its application. In the above case the difficulty in applying the law exactly and completely to a given

natural phenomenon is sometimes so great that the scientific application of general principles to a particular case should be considered as a true advance, although the result obtained by the utilization of the more general principle actually contains nothing absolutely novel.

However great the importance this purely inductive method of research may have had in the past, and always will have, in scientific progress, nevertheless undoubtedly we shall penetrate more profoundly into the essence of these phenomena, when by the second method, based on accurate ideas and their logically deduced consequences, we arrive at a new law of nature; and that is why this method appears the most attractive. It is obvious that we can follow it successfully only on the condition that we have made a fortunate choice of the ideas which are the basis of our theoretical reasoning. But it frequently happens that it is impossible to put these fundamental ideas to the test of experiment, and to verify their value; then the investigator who allows himself to follow the deceptive gleam of badly chosen fundamental ideas is incessantly in danger of ending in error.

Such conceptions, more or less impossible of experimental demonstration, are called *hypotheses;* such is the admission of the existence of a luminous ether filling the universe, an imponderable mass, which on that account escapes our senses, connected with ordinary matter; again such is the supposition that all bodies are composed of indivisible though finite particles, but extremely small, which on account of their minuteness, cannot be directly perceived by our senses. The introduction of hypotheses is, as we have said, absolutely necessary for a knowledge of the phenomena of nature deep enough to lead us to the discovery of new laws. As these can be submitted to experiment, the result shows not merely the truth, but also the value of the hypothesis; since one failure would demonstrate not only the inapplicability but also the falsity of the hypothesis from which we started.

Thus hypothesis is a very important aid to science; it is not the goal (at least for those who apply themselves to the study of nature) but it is considered to justify its existence by serving as a bridge to connect together the already known facts of experiment and to link them to new facts. The value of a good hypothesis consists essentially in deepening and enlarging our

knowledge of phenomena, that is to say, it serves as a natural law. If at all times, though in different degrees, human nature has always shown a predilection for hypothesis, it is due to the fact that the knowledge of a new law gives more satisfaction if it has been derived by the deductive method from general points of view, than if it had been deduced, by the inductive method, as the consequence of long and exacting experiments.

To resume, we say that from the side of experimental work, that is to say, the observation and the quantitative study of phenomena, the special activity of the investigator should be principally directed to the discovery of the most general laws and the most workable hypotheses. The expression, whether in ordinary language or in formulas, of theories found by the speculative method, has on the one side the advantage of allowing others as well as the discoverer to take part in their verification; and on the other side, the scientist who has taken cognizance of a new theory, which is susceptible of general application, can forsee a multitude of the details of its phenomena.

"He who knows the law of phenomena has not merely acquired knowledge but also the power of affecting, as occasion arises, the course of nature itself and making it work according to his will and to his advantage. He sees the future progress of these phenomena. In fact he possesses those powers, which in the age of superstition were looked for in the Magi and the prophets." (Helmholtz, *Goëthe-Rede*, 1892.)

To-day, we are in possession of a certain number of experimental laws and hypotheses susceptible of the widest application to different branches of the natural sciences, the didactic exposition of which should properly precede that of the sciences themselves; this is particularly true of pure physical chemistry. In fact, the principle of the indestructibility of matter owes its clear and full expression to chemical research; the principle of the indestructibility of energy gave birth to a new branch of chemistry, thermochemistry; and the principle of the transformation of heat into external work (the second principle of the theory of heat), is nowhere shown to be more fruitful than in its application to chemical phenomena; lastly, the hypothesis of atoms and molecules seems indispensable for the complete comprehension of the nature of chemical combinations.

SPHERE OF THE VALIDITY OF THE LAWS OF NATURE.

It has frequently been admitted that a natural law should have an absolute value; to-day it is difficult to accept such an opinion; at least everything points to the fact that no natural law exists of such vast extent. It seems rather that all the laws of nature have a more or less extended value, and that there is always a limiting case where the law fails.

Thus, to give an example, we have serious reasons for thinking that the second principle of thermodynamics would fail if applied to very small quantities of matter. But it is evident that it would not be reasonable, in this case or in similar cases, to elevate this proposition to the rank of a law of nature; let us say rather, in a general way, that the question is not one of knowing whether a law is rigorous or not, but rather of knowing between what limits it can be applied. This idea is perhaps not without importance with regard to certainty (exactness) in scientific research. For it often happens that the progress of science makes it necessary to revise certain long accepted laws; and sometimes we hear allusions to the fallibility of human research. But on looking closely into the matter, we always find that the disputed law has preserved its value to a large extent, and that the progress of science has merely fixed the limits of its legitimate application more precisely. It may even be said that, since the development of the physical sciences, there has not perhaps been one law established by a talented investigator, which has not always kept a vast domain where it remains applicable; or which, in other words, has not remained a natural law applicable within certain limits.

Thus it cannot be said that the electromagnetic theory of light, the old optical theory established by Fresnel and his successors, has lost its importance; on the contrary, lately, as in earlier times, the old theory has explained a multitude of phenomena perfectly. It is only in certain cases that it fails, and there exists a series of relations between the optical and electric phenomena which were not foreseen. It follows from these that the electromagnetic theory of light realizes considerable progress, without belittling the importance of Fresnel's theory.

Instead of physical theories falling like autumnal leaves in the course of ages, it seems rather that, within certain limits,

they have eternal life; every new law which has been accepted by its eminent contemporaries will doubtlessly, in its future developments, have to submit to certain limitations, but none the less it will remain for all time the synthesis of a certain sum of truths.

SYSTEM OF MEASUREMENTS.

As we have already said, it should be the constant effort of the physicist to deduce from his observations the numerous facts that are verifiable by observation. The description of a phenomenon is often very difficult, when it furnishes no data as to the degree of greatness of the actions observed.

The units of measure were established at first quite arbitrarily, and for reasons more or less of a practical or historical nature. This refers to the fundamental units of length, of mass, of time, and of temperature. The units of other dimensions, which the progress of physics has introduced in greater and greater number, might have been chosen arbitrarily in the same way. Let it suffice to recall the expressions: pressure of (*a*) atmospheres, luminous intensity of (*b*) candles, engine of (*c*) horsepower, heat of combusion of (*d*) calories, etc.

A decisive progress was marked when Gauss (1832) and Weber (1852) showed, by the examples of electric and magnetic dimensions, that it was possible at least to limit this arbitrariness if it could not be suppressed. The method inaugurated by these savants consisted *in basing the new units on physical laws.*

For example, instead of comparing the intensities of electric currents with one another in any way whatsoever, and limiting themselves to relative measurements, they have adopted the reciprocal electrodynamic force of the currents as a basis for referring the intensity of a current to the aforesaid fundamental units; thus they have defined the unit of intensity of a current in absolute value, the intensity of a current of which two portions 1 cm. long placed on the same axis at a sufficiently long distance of L cm. exercise a repulsive force of $\frac{1}{L^2}$ upon each other, valued in mechanical units. The unit of resistance is the resistance of a conductor where the unit of current thus defined disengages in the unit of time a quantity of heat equivalent to the unit of work. The unit of electromotive force is defined,

by the help of Ohm's law, as the tension at the extremities of a conductor with a resistance 1 traversed by a current of intensity 1.

This method, which refers the new units to a small number of already existing units, and which replaces the simple comparison of the new dimensions by their value as a function of other dimensions, the units of which are known, is not, however, absolutely free from arbitrariness. In the preceding case, to define the unit of intensity they might just as well have chosen another form and another disposition of the portions of the current; thus, as Gauss and Weber have pointed out elsewhere, a system of electric measurements could have been established by using as a basis, instead of the electrodynamic phenomena, the electrostatic forces set in action at a distance by free electricity. In spite of that, it is evident that the principle of Gauss and Weber has considerably decreased the arbitrariness. What is still more important is, that by the introduction of the absolute system of measurements, the numerous physical laws take a very simple expression, on account of the disappearance of certain factors of proportion; and also that the absolute system summarizes for the physicist a mass of the details of knowledge, and gives the idea and the explanation of many particular circumstances in the kind of measurements applied to the most varied domains.

Besides one is in no way limited to the choice of the four fundamental units named above and generally employed hitherto; by the help of Newton's law of gravitation, mass can be expressed in functions of length and of time (Maxwell); by means of the equation for gases $p.v. = RT$, by making $R = 1$, the temperature can be expressed as a dimension of energy in mechanical units. For many reasons such changes do not appear advantageous, at least up to the present time, and it will be better to await the discovery of new natural laws before seeking to reduce the number of fundamental units. Naturally these would be chosen in such a way as to obtain great accuracy in the direct measurements; length, mass, time, and temperature meet this requirement well, but not energy, which for this reason cannot be considered as available for a fundamental unit.

THE INDESTRUCTIBILITY OF MATTER.

From numerous experiments we have learned that there is no variation of the mass of a body, neither from physical changes (*e.g.*, pressure, temperature, magnetism, etc.), nor from chemical transformations (the mass being measured, for example, by terrestrial attraction) (Lavoisier). A large number of chemical analyses and syntheses bear witness to the exactness of this proposition: notwithstanding the potent chemical phenomena taking place on the sun's surface, the action of this star on the planets does not change, an obvious proof that the total mass of the sun does not vary under the influence of these phenomena.

The question of knowing if the weight of the products of a reaction is equal to the sum of the weights of the reacting substances has been submitted to an exact verification by H. Landolt. He found that in fifteen cases examined the variation in the weights involved in the chemical reaction scarcely reached a few millionths and never exceeded the errors of weighing (0.03 milligrammes).

TRANSFORMATION OF MATTER.

The properties of a substance vary with the external conditions to which it is subjected; however, there is generally only a small variation of the physical properties corresponding to a small change in the conditions, particularly of pressure and of temperature. If, on the other hand, several different bodies, such as sugar and water, iron and sulphur, etc., are put in contact, even maintaining the external conditions constant, a great modification of their properties is produced, which goes so far as the formation of bodies which from several points of view are quite different to the original substances. Thus the same substance can assume, while the external conditions remain the same, quite different external properties,—matter undergoes transformation.

According to the observations made up to the present time, this variability of matter is confined to certain conditions. The law of the indestructibility of matter puts the first limit upon it, for the quantity of matter remains invariable during all these changes. Experience has provided us with another example in this sense: the results of numerous and difficult undertakings in the laboratory, from the attempts of the alchemists to trans-

form metals into gold, to the admirable syntheses of present-day organic chemistry, have taught us that it is even possible to transform equal weights of substances of a different nature from one to the other condition.

TRANSFORMATION OF ENERGY.

Second Principle of the Mechanical Theory of Heat.—Although the law of the conservation of energy has given us quantitative relations which always recur in the transformation of different forms of energy (external work, heat, internal energy) from one to the other, what is known as the second principle of the theory of heat has made known to us the limits to which the power of transformation of the different forms of energy must submit. From a purely qualitative point of view, this may be expressed as follows: *Exterior work, as well as the kinetic energy of masses in motion, can completely transform themselves in various ways from one to the other, and inversely; they can, similarly, transform themselves into heat* (perhaps the simplest way of utilizing the work is to put in motion masses of matter, which from the friction produce heat, while losing their kinetic energy); *but the inverse transformation of heat into work can only take place in limited proportions* (Carnot and Clausius' Principle).

The current of thought which leads us to seek just at what point the different forms of energy are transformable from one to the other, and to admit that there is a limiting physical law, is in reality the following: As fruitless as were the efforts of numerous inventors to construct a machine that would continually do work without the expenditure of energy to sustain the motion, so fruitful was the idea that these failures were due to a law of nature. On the ground fertilized by the lost illusions of the unfortunate inventors, a magnificent tree has grown, a knowledge of the law of the indestructibility of energy, the precious fruits of which Mayer and Helmholtz have gathered. But even to the inventor, perfectly imbued with the truth of this law of nature, the existence of a machine capable of doing work in the external medium and of yielding it without expense, did not appear an impossibility. According to the law in question, external work and heat are equivalent; they are two forms

of energy. But energy in the form of heat is abundantly distributed, in such a way that only an apparatus is needed to harness this energy and to return it to us in the form of work by making our machines go. For example, this apparatus could be plunged in a large reservoir of water whose immense store of energy it would transform into useful work; it would make the steam engines of our ships useless, for the screw would continue its rotary motion at will, at the expense of the inexhaustible quantity of heat contained in the ocean. Such an apparatus would also be, from a certain point of view, a *perpetuum mobile* (perpetual motion) in no way contrary to the first principle, but working conformably to this principle, deriving it from the heat of the exterior medium and restoring it in the form of work; this work, by its utilization, will reproduce heat (in this case by the friction of the ship and the screw) and the cycle would recommence anew.

Unfortunately this apparatus, which would make carbon useless as a source of energy, appears to be a chimera, like the *perpetual motion* of the inventors of the Eighteenth Century, who tried to create work from nothing; to say the least, numerous attempts have made this more than probable. We thus arrive, by the same method as for the first principle, by drawing up the balance sheet of so many useless efforts, at this proposition, *that an apparatus which could continuously transform into external work the heat of the ambient medium is in contradiction to a natural law, and is therefore impossible.* If the admission of this principle impoverishes the inventive spirit of man of one problem, on the other hand it enriches natural philosophy with a principle, the applications of which are almost inexhaustible.

This conclusion, which is primarily of a negative character, with the aid of certain reflections and by the help of certain experimental facts, serves to establish the quantitative expression of the law which limits the transformation of energy, and is known as the *second principle of the theory of heat.* The fundamental reflections which led to this principle have been clearly expressed by Carnot,[1] and this in 1824, which is remarkable because it was before the principle of the conservation of

[1] Reflexions sur la puissance motrice de feu, Paris, 1824. Reprinted by Hermann, 1903.

energy was defined. To Clausius[2] belongs the immortal merit of having formulated this principle as an extraordinarily fruitful, universal law, and of having mathematically developed its consequences with exactness and universality.

Let us try to give the preceding proposition the form of a general principle of physics; the following ideas will serve:

I. *Every phenomenon which produces itself in a given system, that is to say, without the intervention of any form of outside energy, is capable, with the aid of suitable appliances, of producing a certain quantity of external work.*

By the term phenomenon, we mean every variation of a system, which causes it to pass from the initial state to a different final state. If an outside energy intervenes, the system can naturally produce a certain quantity of work; for example, an electromotor when supplied with a sufficient quantity of electric energy, represents, at least in principle, an inexhaustible source of external work.

The question now is to know what is the best method of utilization; that is, how to make a given phenomenon yield the maximum quantity of external work. For that it is above all manifestly necessary that the apparatus used should be as perfect as possible from the technical point of view, that it should work with the best practical effect, that care has been taken to avoid the loss of external work from secondary defects (friction or analogous occurrences, the imperfection of a badly fitting piston in a cylinder in which it compresses or expands gas or steam, defects of insulation in electrical conductors, loss of heat in thermal machines, etc.), but it is still more necessary that in every phase of the proceeding the force and the resistance to be overcome should be nearly equal. If the opposing force is the smaller, the change takes effect in one direction, if it is the greater it acts in the opposite direction, and as theoretically all losses should be avoided, it is obvious that the quantity of work obtained when the change is made in one direction is equal to that which it must expend to make it in the other direction. In such cases the action is said to be *reversible;* we shall see shortly cases in which this ideal can be indefinitely approached

[2] "Ueber die bewegende Kraft der Waerme," Pogg. Ann., lxxix, 369, 500. (Clausius has collected all the papers which have appeared since 1850 in a work entitled "Mechanische Waerme Theorie," Brunswick, 1876.)

(at least in principle). Let us admit that in general this is possible, and let us consider this proposition to be established:

II. *A phenomenon produces the maximum of external work when it is reversible.*

We can easily perceive that propositions I and II are in perfect agreement with the proposition that no appliance can continually furnish work at the expense of the heat of the ambient medium. According to I, since a phenomenon can only produce a limited quantity of work, such an appliance can only be a machine functioning in a periodic manner, which after a certain lapse of time returns to its starting point; according to II, this machine, in the most favorable conditions (with an ideal construction), has not, after a time, absorbed any external work, and in any case has not produced any, since it must function reversibly to avoid losses, and that at each motion in one direction it produces just as much work as it absorbs in the inverse motion.

As examples of phenomena which produce themselves, in the sense of proposition I, we might mention the fall of a stone on the ground, the mixture of two gases or two miscible liquids with each other, the diffusion and solution of a solid in a liquid, and, above all, the innumerable chemical phenomena which are produced spontaneously. The problem of determining the maximum of external work which can be obtained in each particular case, that is, in the sense of proposition II, the question of what means to use, to make a phenomenon reversible, is of the greatest importance, and its solution in certain special cases has led to discoveries of great importance.

Let us place two bodies of different temperatures in contact, then heat will pass from the warmer to the colder body; this phenomenon takes place spontaneously and no work has to be furnished; from proposition I it follows directly that in this exchange of heat, we must for one thing furnish external work to obtain the inverse phenomenon, that is, to make heat pass from a colder body to a warmer.

Clausius has enunciated this last proposition as a special principle: "Heat cannot pass from a colder to a warmer body without compensation, *i.e.*, without the help of an outside energy." But it is evident that this principle is only a particular case of a more general proposition.

To particularize these general explanations we can apply them to two particularly important cases, the first is that of the *isothermic* modifications, and the second is that of phenomena which *consist simply of the transference of heat* (equalization of different temperatures).

THE MOLECULAR HYPOTHESIS.

Although it appears extremely opportune to erect, on the basis of experimental propositions concerning the transformations of matter and energy, a doctrinal edifice in which the results of experience could be arranged in a methodical and obvious order, an hypothesis has been added to these propositions based on experiment, regarding the constitution of aggregate bodies. It was only at the beginning of the last century that this hypothesis, made in antiquity, was revived by Dalton and Wollaston and utilized to give us a clearer and deeper conception of chemical phenomena; it has since become, in a way, the principal guide in the development of physics and of chemistry. According to this hypothesis, an aggregate body does not fill the space which it appears to occupy; it is composed of very small but finite particles, more or less distant from one another, which are called *molecules*. That the interstices between these molecules escape us, that they are not more evident to direct observation than the molecules themselves, and that our senses rather indicate that matter *is* continuous, all these things are due to the minuteness of the molecules and to our incapacity of perceiving such small dimensions. This is not the place to examine whether the molecular hypothesis corresponds with the reality, or whether it does not owe its existence to our lack of power to attain a profound comprehension of the phenomena of nature by adopting other conceptions, or again whether by the development of the theory, we should not some day attain different and clearer ideas of matter; the time has not yet come to open such a discussion. One fact is certain, and that is the only important and decisive matter, that the molecular hypothesis is, in all the natural sciences and most particularly in chemistry, as great and as important an auxiliary as theoretical speculation has ever produced. That is why, in the account we are about to give of theoretical chemistry, we shall never lose sight of the molecular

theory; and shall make use of it in every case where the explanation of facts and clearness and quickness of expression, require it. Up to this day the molecular hypothesis, in its development, has furnished an abundant harvest and has enriched science with positive knowledge; why then shall we not direct our efforts to make our ideas of the world of molecules more definite, and arm our eyes with more and more powerful microscopes to enable us to consider it?

ATOMS AND MOLECULES.

The first great success of the hypothesis of the distribution of matter in separate masses was the simple and intuitive explanation of the law of definite proportions and of multiple proportions, propounded by Dalton, the discoverer of the law, who by this coup caused this hypothesis to be reborn for modern science, like a phœnix from the ashes of the old Greek philosophy.

From the point of view of the molecular hypothesis, the formation of a compound from its elements can be understood in the simplest way, as the combination of the smallest particles of the elements to form the molecules of the compound. It follows then that the molecules are divisible, and their division takes place when a compound is decomposed into its elements. Thus we are led to admit that the molecule itself does not completely fill the space it occupies in a uniform and continuous manner, but that it too is an aggregate of particles distributed in the mass of the molecule; these material particles are called *atoms*. The atoms which form a molecule are all alike, if it is a molecule of an element; but they differ, if they constitute a chemical compound. It is only in the first case that a molecule can consist of a single atom. The force which unites the atoms into a molecule is called chemical *affinity;* to the action of this force is attributed the reason why the properties of the atoms vary according to the molecular structure to which they belong, and why the properties of the compounds are often so different to those of the free elements.

Many experimental facts bear witness in favor of the view, which seems evident, that the atoms of the same element all have the same weight, and that the molecules of a simple chemical compound all have the same composition. Hence it is obvious

that the proportions by weight, according to which the different elements are combined in a chemical compound, are equally those in which they are combined in the molecule of the compound; but as this molecule contains a definite number of atoms, no matter by what process it was obtained, it follows that the composition is always perfectly definite. Further, the molecule can only contain whole numbers of atoms of each kind, numbers which generally are not very large; it follows then *that the proportions in which the elements are combined in the different compounds must be to each other as the atomic weights of the elements, or as simple multiples of their atomic weights.* Experiment perfectly verifies this deduction of the atomic theory; the proposition contains the law of definite proportions and of multiple proportions, and it greatly extends the experimental law by giving a precise and tangible idea of the purely empirical equivalents. In the meaning of the atomic theory, it is evident that the equivalents and the atomic weights must be in rational proportions; sometimes these proportions are not obtained without arbitrariness or without new experimental facts; and when we shall consider the determination of the atomic weights, we will indicate the methods which lead us to the values of the relative atomic weights, actually admitted to be exact (within the inevitable errors of observation).

CLASSIFICATION OF NATURAL PHENOMENA.

For a long time natural phenomena have been divided into *physical* and *chemical* phenomena; in the first the composition of matter plays generally only a secondary or subordinate rôle, whilst in the second the chief importance is laid on the changes in composition. Putting ourselves in the point of view of the molecular theory we see in the physical processes changes which leave the molecules intact; the chemical processes, on the contrary, cause changes in the composition of the molecules. It is clearly shown that this division is based on good and profound reasons by the very great distinction between physics and chemistry, both in the methods of work and of research, as well as in those of instruction; this is so much the more surprising because physics and chemistry pursue the same end, which is to reduce the complexities or the external world to the simplest

possible phenomena and laws. But such a separation does not appear to be fruitful for the future; at least that is generally admitted to-day, when physicists and chemists ardently work together on the borderlands of their sciences.

Since the propositions of the theory of heat claim to be applicable to all the phenomena of the external world, the question arises of knowing if it would not be possible to class these phenomena in a simple way, according to their thermodynamic qualities. In fact on examining the fundamental formula

$$A - U = \frac{dA}{dT}$$

we see at once that the following limiting cases demand attention.

1. $U = A$, *the variations of total energy and of free energy are equal.* Then the coefficient of temperature of A, and consequently that of U, are both zero, that is to say, that *the temperature has no influence on the phenomenon under consideration*, at least so far as concerns the thermodynamic properties. Inversely, if this condition is fulfilled, we have $A = U$. According to the way in which all these systems behave, whether they are acted on by the force of gravitation only and by the magnetic and electric forces, then the actions of these forces can be represented by a function of the forces (potential) independent of the temperature. Often, in chemical phenomena, A and U are equal, at least approximately.

2. $U = o$, then $A = T\frac{dA}{dT}$, where A *is proportional to the absolute temperature.* The expansion of a perfect gas and the mixture of two dilute solutions are included in this case, where the influence of temperature acts very simply (a gaseous thermometer).

3. The third limiting case, $A = o$ would give

$$U = -T\frac{dA}{dT},$$

that is to say, it can only be produced at a particular point of temperature. A can easily be very small in proportion to U in a sufficiently large range of temperature; and as in that case the coefficient of temperature of A would be very large, it follows in this case that temperature has a very great influence (for example, evaporation, fusion, dissociation, and in a word the "physicochemical" phenomena, properly so-called).

The third case is not of such striking simplicity, and has not given birth to such important hypotheses as the first case, which has introduced the attractive forces into science, and the second case which has been decisive for the molecular theory.

The cases $U = o$ and $A = o$ do not indicate any variation in the thermodynamic sense; but as such variations do exist in reality (the motion of a mass in a direction perpendicular to that of gravity, the change of an optical isomer to its optical antipode) and are even sometimes very important, thermodynamics only provides us with a very circumscribed means of classification for all the phenomena, although here it has been able to give us important points of view.

The Amount of Thorium in Sedimentary Rocks. J. JOLY. (*Phil. Mag.*, xx, 125.)—A determination of the amount of thorium in 34 different calcareous rocks gave a minimum of less than 0.03×10^{-5} and a maximum of less than 0.33×10^{-5} Gm. of thorium per Gm. of rock. Since calcareous rocks do not constitute more than 5 per cent. of the bulk of the sedimentaries upon the land, it is concluded that the influence of the surface materials in ionizing the air over calcareous districts cannot be directly inferred from these results.

Recovering Zinc from Galvanized Iron Scrap. ANON. (*Brass World*, vii, 11.)—A recent French patent claims the recovery of zinc from galvanized iron by placing it in a tumbling barrel or iron with perforated staves, revolving in an iron tank filled with a boiling solution of slightly basic zinc chloride. When the evolution of hydrogen ceases the barrel is removed and the scrap washed. Only a small amount of iron is dissolved, which can be precipitated by calcium chloride. The zinc goes into solution as zinc chloride. At the end the solution is highly basic and can be restored to the slightly basic condition by adding hydrochloric acid.

Cold Vulcanization. B. BYSOW. (*Zeit. Chem. Ind. Kolloide*, viii, 47.)—The sulphur chloride preparations were made by distilling the commercial product, collecting the fraction passing over at 136° to 138° C., and dissolving different quantities of sulphur in portions of this. The three preparations contained (1) 51.09 per cent. of chlorine and 48.91 per cent. of sulphur; (2) 46.40 per cent. of chlorine and 53.60 per cent. of sulphur; (3) 34.35 per cent. of chlorine and 65.65 per cent. of sulphur. Solutions of 5 grammes of each in 1 litre of dry petroleum spirit were used to

vulcanize pieces of sheet para rubber and the vulcanized samples extracted with acetone and analyzed. The results showed that Weber's theory, that in cold vulcanization the fixation of sulphur is dependent upon the extent to which the chlorine combines with the rubber, and the quantity of sulphur fixed is governed by the amount of heat generated by the combination of chlorine with the rubber, is untenable.

Resistance of a Concrete Building to Fire. ANON. (*Eng. Record*, lxiii, 137.)—A concrete building occupied by the Moser Paper Co., of Chicago, burned for four hours with only slight damage to the building, such as discoloration of the walls and ceiling and surface spalling at a few points. The material burned was a stock of paper stored on shelves and in wooden packing cases.

Study of the Fire-fly. H. E. IVES. (*Elect. World*, lvi, 804.)—An investigation of the nature of the glow produced by the fire-fly indicates that the visible rays are the only ones emitted, except for the "body-heat" of 40° to 50° C. On this basis the luminous efficiency of the fire-fly is calculated to be 50 candlepower per watt, as compared with 2 to 3 candlepower per watt in the most efficient of the electric arcs.

Discovery of a New Star. G. RENAUDOT. (*Rev. Gen. des Sciences*, xxii, 50.)—Mr. T. E. Espin, of Durham, England, discovered a new star on Dec. 30, 1910, in the following position R.A. 22hr. 32′ 9.5″. Decl. + 52° 15′ 21″ in the small circumpolar constellation of the Lizard, in the Milky Way. Its magnitude is 7.5. It is in excellent position for observation in northern latitudes, and is easily recognized by its very characteristic red color. Spectral analysis reveals four particularly brilliant lines in the red, the yellow, the blue-green, and the blue. The red line of hydrogen is the most intense.

Production of Zinc (or Tin) and Titanium Alloys. (A Patent by A. J. ROSSI, Niagara Falls, N. Y.)—A zinc-titanium alloy is produced by adding titanic acid, alone or with zinc oxide, to a molten mixture of zinc and aluminum, and heating to a temperature sufficient to insure reduction by means of the aluminum. By the use of tin and tin oxide in place of zinc, a tin-titanium alloy can be obtained.

Standard of Electro-motive Force. E. WARBURG. (*Rev. Gen. des Sci.*, xxii, 94.)—The Physikalisch-technische Reichsanstalt, has adopted, since Januaray 1, 1911, the value of 1.0183 international volt, at 20° C., as the electro-motive force of Weston's standard pile.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting, held Wednesday, April 19, 1911.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1911.

Secretary, R. B. OWENS, *Acting Chairman.*

Additions to membership since last report, 6.

The Paper of the evening entitled "Engineering as Related to the Structure of the Body Politic" was presented by Mr. John C. Trautwine, Jr., of Philadelphia, who spoke, in part, as follows:

Without engineering, human co-operation, upon a large scale, is impracticable.

War was probably the first conspicuous instance of such co-operation, and, in warfare, engineering has always been the chief reliance. Indeed, until a little more than a century ago, "the engineer" meant "the military engineer." There was no other.

With the appearance of the steam-engine, practically a century ago, co-operation first became a notable feature of industrial life. The steam-engine brought into being the modern corporation, which is now rapidly bringing all non-governmental industry within its bailiwick.

As a result of this, the community is being (for the most part unconsciously) schooled and trained in the all-important art of organization, and being converted from an unorganized mob into a drilled and correspondingly efficient industrial army.

Concurrently, our governments, city, state and national, are forced, in the protection of the individual against the domination of this growing power, to assert their authority and to assume ever new and stronger powers, at the same time, enormously extending their own industrial activities.

This must result in the eventual assertion, by the people, of their control over all industrial operations, with resulting benefits (to rich and poor alike), with which any private and exclusive individual wealth is as incomparable as it is with that already brought to us by our operation of our public streets, parks, schools, post-office, etc.

After a brief discussion the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract from Proceedings of Stated Meeting held Wednesday, April 5, 1911, and the adjourned meeting held Wednesday, April 12, 1911.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 5 and 12, 1911.

DR. GEORGE A. HOADLEY *in the Chair.*

The following reports were presented for final action:

No. 2469.—Crisfield's Moisture Determinator for Coke, etc. Longstreth award. Adopted.

No. 2476.—Roper Safety Propeller. Longstreth award. Adopted.

No. 2496.—Branch Electric Light Shades. Certificate of Merit. Adopted.

The following reports were presented for first reading:

No. 2458.—Colby Electric Furnace for Melting Metals.

No. 2479.—Behrend High-Speed Electric Generator.

No. 2486.—Jackson's Improvements in the Stability of Dams. Advisory. Adopted.

No. 2488.—Grover's Clothes Steamer. Advisory. Adopted.

No. 2501.—Wolf Liquid Gas Apparatus and Process.

No. 2502.—Luehr's Improvements in Air Purifying Apparatus. Advisory. Adopted.

R. B. OWENS,
Secretary.

FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

The closing exercises of the School were held on the evening of Friday, April 21, 1911.

Presiding Officer, James M. Dodge, Vice-President of The Franklin Institute.

Remarks relating to the work of the School and the Alumni Association were made by Mr. Dodge, Director Thorne, and James C. Wobensmith, President of the Alumni Association.

President Chessman A. Herrick of Girard College delivered an address to the graduating class, an abstract of which appears in this issue of the JOURNAL.

REMARKS OF PRESIDENT CHEESMAN A. HERRICK, OF GIRARD COLLEGE, AT THE CONCLUSION OF THE WORK OF THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

April 21st, 1911.

President Herrick said in part: "I am pleased to come to these exercises and to bring the greetings of Girard College to the Franklin Institute at the close of its year of school work. In the first place it seems fitting that I should acknowledge the indebtedness of Girard College to this Institution, for it was a distinguished Professor of Architecture of the Franklin Institute—then in the early years of its history—who designed the first group of buildings for Girard College.

By common consent the Main Building of Girard College is to-day the purest type of Greek architecture in the world. These original buildings stand as the finest example of their time of good construction, but more than this, in their imposing grandeur they are ornaments to Philadelphia, and in addition a protest against the many flimsy, cheap, incongruous and over-wrought buildings now so common. The work of Thomas U. Walter at Girard College and elsewhere in Philadelphia, and particularly in the capitol extensions at Washington, D. C., has placed the whole country under obligation to the Franklin Institute.

I am of those who are without the benefits of specialized scientific or engineering education, but I am not unmindful of the great debt which we all lie under for the discoveries in experimental science, and for the application of science to every-day life, which have been contributed by the Franklin Institute and institutions of its kind; and I trust I shall always be fair enough to give the just dues to the work of these institutions in the progress of our times.

The name of Franklin in the 18th century signified much of scientific development during that period, and particularly the utilization of science in order to make life more tolerable. Count Rumford, who had been the moving spirit in the establishment of an earlier institution of the same character as the Franklin Institute in London, stood for much the same tendencies as did Franklin. Franklin had been ridiculed not a litttle in some quarters as the father of the vulgarities of the American people, as the "bread and butter philosopher," etc., but let us not forget that it is from such philosophers as Franklin and the application of scientific discoveries that the world's progress has come about.

We recently buried from Girard College our Chief Engineer, who had been in the service of the Institution for forty years. The service of this man saw the change from oil and gas lighting to the present tungsten incandescent burners, and from coal stoves in individual buildings for heat—first, to steam plants located in or near the buildings, and finally to one central heating plant. There have been corresponding changes in the production and distribution of power, until at present there is one

central heat, power, and lighting plant. We have neither noise, dust, worry, nor thought of our power plant, and it is never present to our consciousness except as we have its results, and its results are always satisfactory.

These great changes have come not because of our engineer or because of our contributions—but because of the work done by the Franklin Institute and like institutions, the results of the work of which have been brought to our doors in such form as to enable us to utilize them.

Especially do I congratulate you on the educational work of the Franklin Institute. Upon investigation it appears that your attendance during the year just closing is something like 50 per cent. greater than in the preceding year, and this indicates a tendency which I trust may be marked in the years to come, so that the Franklin Institute will be driven by necessity to the erection of a new and more commodious building in which to carry forward its educational activities.

Your Secretary informs me that these night courses for apprentices, draughtsmen, etc., have been continued for nearly a century, and further that many of the students from these courses have attained to high rank and great usefulness. In these days we hear much of continuation schools, education for the artisan classes, part time schools, and the like, but it would appear that for nearly one hundred years the Franklin Institute has been making a wise and sane contribution to education of this sort, and it may be that when Cincinnati and Pittsburgh, Boston and Pittsfield and a hundred other places over this country shall have adopted from Munich and other German cities the ideals of the continuation school and put them into practice, we shall realize what the Franklin Institute has done for quite a hundred years in the education of apprentices.

I have in the next place a more personal word to those who have been in attendance at the School of Mechanic Arts. It is to almost every man a critical time when he first goes to employment, and every one of experience and observation here present will agree with the statement that the manner in which one spends his leisure hours is a matter of supreme importance. The Patron Saint of this Institution offers a significant example. When Franklin found himself in London he used every opportunity for improvement by attendance upon lectures, discussions, and by the pursuit of all branches of learning. Almost immediately after his return to America and while he was a young man, he originated for the mutual improvement of all its members, the famous Junto Club. Out of this Club there came the Philadelphia Library and the American Philosophical Society, but the spirit of the Junto Club came quite as truly to the Franklin Institute.

In my judgment the Franklin Institute has rendered a most useful and far-reaching service in the opportunities it has afforded for continued education to a large number of young men. The young men of to-day will find greater opportunities for self-improvement than were afforded in Franklin's time, but they will also find many more insidious and alluring temptations than were presented to Franklin to engage in idle and injurious amusement. The motion picture shows, the vaudeville, the dance hall, the

joy ride, and the amusement park are but a few of the attractions by which the youth of the present are lured from the paths of virtue, and the fields of intelligence.

Those who give themselves over to these solicitations will have their intellects stunted, and characters dwarfed. To such the door of large opportunity will be closed. There is nothing which the young man of to-day needs more than continued education after he takes up his life-work. I rejoice that here is afforded opportunity for such education, and also that here are young men who are willing to make the sacrifice in order that these opportunities may be embraced.

The advantages of continued education are two fold: first, in preventing the undermining effect of vapid and evil amusements, and second in the direct service which such education will render. The young man without definite interests and associations in life is likely to fall into the habits of a "sport," and shortly to unfit himself for his regular work, by late hours and the outside associations which he forms. So important is the matter of conduct outside of regular employment that many large concerns are feeling a moral obligation and self interest in the life and activities of their employees.

But the advantages of this continued education are more positive and direct. Persons who fit themselves for large usefulness will not fail to get recognition. As never before the demand is for efficiency,—efficiency of mind, and efficiency of hand. The person who gains for himself by education good judgment, insight, mental balance, point of view, and all that combination of qualities which we recognize in the educated man, cannot fail. The world is asking for men of this sort in every walk of life. They will be quickly singled out from the bleareyed, helpless, dawdling class which think that any preparation and any service is good enough.

In brief, education pays: broad, liberal, fundamental education pays; highly specialized and narrowly technical education pays; education pays in life's satisfactions; education pays in money return. No one has more convincingly set forth the truth of this last statement than has your presiding officer of the evening, Mr. James Mapes Dodge, in a well-known address of his, "The Money Value of Education."

I count myself fortunate in having the opportunity of participating in these exercises, and I take this occasion to say to the Managers of the Franklin Institute that I trust they will continue to stimulate and expand the work of their School of Mechanic Arts: And to you who have been students I can but express the hope that you will continue the good work on which you have entered, and not weary in perfecting and improving yourself for life's duties.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL OF MECHANIC ARTS OF THE FRANKLIN INSTITUTE FOR THE SEASON OF 1910-1911.

The School of Mechanic Arts has given, this season, the most complete series of courses in its history and, although some of its classes have been small and many of the students have not done their proper share of work outside of school hours, the results have been very satisfactory and gratifying, and the Institute should feel encouraged in continuing the expansion of this important part of its work.

This being a night school with nearly all of its students working at their trades and business during the day, it is rather surprising that such technical subjects should interest and hold them as well as is actually the case, and if it were not that they are seriously determined to learn the basic principles and best practices of these arts in order to better their positions, the effort to present them would seem much less hopeful. As it is, the program should be continued so that when the Institute is permanently fixed in a suitable building with proper accessories, it can take a leading position as a night school of technology.

I wish to express my appreciation of the cordial co-operation of my associates and assistants, Messrs. H. E. Hutchins, H. P. Tyson, H. C. Towle, Clement Remington, I. P. Pedrick, John Burt, G. T. Sharp, A. N. McConnell, Frank H. Lobb, and W. W. Twining.

WM. H. THORNE,
Director.

HONORABLE MENTION.

For their interest, industry and success during this season, the following students have received certificates of Honorable Mention:

DEPARTMENT OF DRAWING.

Junior Mechanical Class.

Edwin L. Gibson
George Schick
Malcolm V. D. Remington
Jonathan Tracey
John H. Frank
G. Frank Brooks
Harry E. Edginton
Edward Battersby
George P. Read
Harry Letzerch
George H. Schwarz
Clarence Gaunt
Arthur Eyre
James R. Johnstone
Warren Russell Snow
Elmer W. Coates
Herbert Jayes

Intermediate Mechanical Class.

Raymond West Betts
Richard Warren
Walter F. Henshaw
M. J. O'Rourke
Fred Gutekunst
Archie F. Murray
Waldemar Rival
Harry Theurer
Leonard Gutekunst
Jeremiah Driscoll
George Schick
Richard Warren, Jr.
M. P. Gregg
Wilbur S. Austin
Ray Sutton
John Tarin, Jr.
John A. McDowell
Robert G. Booth

Senior Mechanical Class.

John T. Dawson
Richard Warren, Jr.
Paul Eichler
Howell J. Floyd
Frederick Rohlfs

Architectural Class.

William S. Bardsley
Raymond C. Harrison
J. Albert Raith
C. Nelson Rocholl
Howard C. Tomlinson
Edgar Worley
William R. Berger
Leon J. Fleischman

Free Hand Class.

H. Walter Stephenson
Theodore A. Nicholson
Leslie M. Holloway
Charles W. Weber
John Zimmerman
John Guarini
Harry E. Donohue

DEPARTMENT OF MATHEMATICS.

Algebra.

A. B. Kurtz
Charles Carman
A. C. Chancellor
E. Baumer
Aage Johanson
William Meinel

Geometry.

Charles Crook, Jr.
Walter H. Dardenne
B. B. Roberts

Trigonometry.

Charles Crook, Jr.
Walter H. Dardenne

DEPARTMENT OF MECHANICS.

Applied Mechanics and Strength of Materials.

Joseph M. Hooper
Warren M. Stone
Robert J. Heiserman
Robert T. Aiman
E. R. Glenn
Albert Ware

Elements of Mechanism and Machine Design.

John Senior — Harry Plant
Henry O. Pohrt — Henry T. Schairer

Structural Design.

Robert J. Heiserman — Robert T. Aiman
Warren M. Stone

Steam Generation: The Steam Engine and Other Prime Movers.

Herbert Ainsworth — Paul G. Binder

DEPARTMENT OF NAVAL ARCHITECTURE.

Leroy V. Calhoun — S. B. Furstenau
J. N. Thompson — A. Sickler
A. H. MacDade

The following students, having completed a two years' course with satisfactory results, are awarded

CERTIFICATES.

MECHANICAL DRAWING.

William Belfield — William Schwindt
Julius M. Netzer — Paul Eichler
Richard J. Warren — George Goldsmith
Harry Haman — Walter L. Bower
Howell J. Floyd — M. J. O'Rourke
John T. Dawson — Frank J. Schmieg
Pasteur L. Croxton — Harry Letzerch
Frederick Rohlfs

ARCHITECTURAL DRAWING.

Charles M. Carroll — Samuel Lanard Amey
J. Albert Raith — Edward Cogan
Frederick Sponheimer

MATHEMATICS.

Algebra—Geometry—Trigonometry.

Warren M. Stone — Charles Crook, Jr.
Robert T. Aiman — Walter H. Dardenne
Robert J. Heiserman — C. H. Mahler

DEPARTMENT OF MECHANICS.

Elements of Mechanism and Machine Designs.

John Senior — Henry O. Pohrt
Henry T. Schairer

In the Department of Drawing, Scholarships from the B. H. Bartol Fund have been awarded to the following:

FALL TERM.

Edwin L. Gibson	James R. Johnston
John Dawson	William S. Bardsley
G. Frank Brooks	H. Walter Stevenson

SPRING TERM.

Fred Gutekunst	Ray Sutton
George Schick	Edgar Worley
Herbert Jayes	Theodore A. Nicholson

SECTIONS.

Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, March 23d, at eight o'clock. Mr. James Christie, Temporary Chairman. Forty members and visitors were present.

Mr. George L. Norris, Engineer of Tests of the Vanadium Sales Company of America, presented the communication of the evening on "Vanadium Alloys." The speaker reviewed the history of Vanadium from its discovery by Del Rio in 1801 to the present time. Reference was made to the work of the numerous investigators of this metal including Sir Henry Roscoe, Moissan, Cowper-Cowles, Arnold and others, and the results obtained by them. The characteristics of Vanadium were described as well as its use in alloying with iron, steel, copper, nickel, etc. A number of lantern slides of manufactured products: automobile forgings, piston-rods and locomotive springs, and photomicrographs of sections of steel were shown.

There being no further business the meeting adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—The Stated Meeting of the Section was held in the Hall of the Institute on Thursday, March 30, 1911, at 8 P.M., with Dr. R. B. Owens in the Chair. Fifty-two members and visitors were present. The minutes of the previous meeting were read and approved. Mr. G. B. Heckel, of Philadelphia, publisher of *Drugs, Oils and Paints,* delivered a lecture on "Materials Used in the Manufacture of Paints," in which he described the preparation of each constituent of a paint from the corresponding ore or other raw material. Thus a description was given of the manufacture of white lead by various processes, of the preparation of barytes and whiting from their ores and of the production of zinc oxide from franklinite and of lead sulphate from galenite by metallurgical treat-

ment. The technology of linseed oil, china wood oil, and oil of turpentine was discussed, as was also the manufacture of dryers and of colored pigments.

The address concluded with an explanation of the rôle of each constituent in the mixed paint. The lecture was illustrated by means of lantern slides.

Dr. Goldsmith, Dr. Williams, the Secretary, and others, discussed the paper with Mr. Heckel. A vote of thanks was given Mr. Heckel and, on motion, the meeting adjourned.

JOSEPH H. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, April 6th, at eight o'clock. Mr. Thomas Spencer Temporary Chairman. The minutes of the previous meeting were read and approved.

Mr. W. S. Barstow, of New York, then presented an interesting communication on "Small Public Service Properties and Their Future." The paper was devoted to small electric railway, power, gas and electric light plants. The financing and maintenance of such enterprises were given full consideration. Many suggestions on the economical management of such plants were offered interspersed with numerous interesting incidents from the speaker's professional experience.

In the discussion which followed the paper, Dr. Goldsmith and Dr. Owens and the Chairman took part.

A vote of thanks was tendered Mr. Barstow, and his paper was referred to the Committee on Publications. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Photography and Microscopy.—A meeting of the Section was held on Thursday evening, April 13, at eight o'clock. Forty-three members and visitors present. Dr. Leffmann in the Chair. In the absence of the secretary, no minutes were presented. The Chairman reviewed the history of the Section and its work, and referred to the important papers which have been presented at its meeting during the past several seasons. He then exhibited a number of microscopic slides of building materials and lantern photographs of remarkable engineering achievements including numerous bridges and Roman aqueducts. He also described a small four-ampere lamp for photomicrographic illumination, a Nernst lamp and a 100 candle-power incandescent lamp for photographic work, the former two being loaned for exhibition by the Arthur H. Thomas Company of Philadelphia.

Mr. John M. Justice, of Frankford, presented and described a number of lantern views on lightning. He called special attention to the so-called "dark streak" which frequently accompanies a lightning discharge, and exhibited a number of photographic slides which seemed to indicate that it was the reverse image of an ordinary light flash. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, April 20, 1911, at eight o'clock. Mr. Thomas Spencer in the Chair. Present, eighty members and visitors.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Mr. Carl Hering, of Philadelphia, who presented a communication on the Electric Furnace. He compared the combustion furnace with the electric furnace and described the various resistance and arc furnaces now in use. He presented statistical information as to the size, production, and temperature of the large furnaces of the world, and described the details of their construction by means of many lantern slides.

In the discussion which followed the reading of the paper Mr. G. H. Clamer described in detail the furnace devised by Mr. Hering which was referred to only briefly by the speaker.

Further remarks were made by Drs. Williams, Owens, and several others. Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

Election to Membership.

RESIDENT.

MR. WALTER HERBERT FULWEILER, care U. G. I. Co., Broad and Arch Streets, Philadelphia.
MR. WILLIAM T. ALLIGER, 5332 Wakefield St., Germantown, Philadelphia.
MR. W. H. JOHNSON, Philadelphia Electric Company, Philadelphia.

NON-RESIDENT.

MR. C. FRANCIS JENKINS, 1808 Park Road, Washington, D. C.
MR. C. J. KIRK, U. S. Sherardizing Co., New Castle, Pa.

ASSOCIATE.

MR. P. T. SHARPLES, West Chester, Pa.

Changes of Address.

MR. FRANK HEPBURN, Trout Creek, R.F.D. No. 3, Jacksonville, Fla.
MR. CHARLES L. REESE, Sixteenth and Brinckle Sts., Wilmington, Del.
DR. SAMUEL C. HOOKER, care of American Sugar Refining Co., S. Fourth and Kent Avenue, Brooklyn, N. Y.

NECROLOGY.

Mr. Craige Lippincott.—Craige Lippincott, president of the well-known firm of publishers, J. B. Lippincott Company, died at his home on April 6th.

Mr. Lippincott was born in this city November 4, 1846, being the son

of Joshua B. Lippincott and Josephine Craige. He was graduated from the University of Pennsylvania in the class of 1866, when he won honors as a student and athlete. On the death of his father in 1886 he succeeded to the presidency of the firm, which had been incorporated the year before. From that time the firm acquired a leading position among important publishers in this country, its products being of a most diversified character including as they do, works of such a widely separated character as fiction and technology, in each of which fields are to be found publications of the highest standard of excellence.

He was a leading figure in the social activities of the city, and was identified with many of the local clubs and societies. Among the latter, the Franklin Institute in the progress of which he displayed an interest both friendly and material.

Colonel Benjamin C. Tilghman.—After an illness of several months Colonel Benjamin Chew Tilghman died at his home in this city.

Colonel Tilghman was born in Philadelphia on March 17, 1861. His father was the inventor of the well-known sand-blast process which was awarded the Cresson Medal by the Institute in 1872. At the age of sixteen Colonel Tilghman entered the scientific course at the University of Pennsylvania and was graduated in 1881. When he had completed his course he entered the business of the manufacture of sand-blast machinery with his father, and upon the death of the latter became head of the company. In addition to his activities in the world of commerce he was also widely known as a student of military affairs, and was regarded by officers of the National Guard of this and other States as one of the most thoroughly versed in military tactics in the volunteer service.

At the time of his death he held the rank of colonel in the Third Regiment of the National Guard. He was a member of a number of social clubs in this city and of the Franklin Institute.

LIBRARY NOTES.

Purchases.

CHATLEY, H.—The Force of the Wind.
MIE, G.—Lehrbuch der Elektrizität und des Magnetismus.
JACKMAN, RUSSELL, CHANUTE.—Flying-Machines: Construction and Operation.
UNDERHILL, C. R.—Solenoids.
BEDELL, F.—Direct and Alternating Current Testing.
COOPER, J. F.—Naval History of the United States. Two vols.
WALKER, J.—Introduction to Physical Chemistry.
CHESNEAU, M. G.—Theoretical Principles of the Methods of Analytical Chemistry.
LANCHESTER, F. W.—Aerial Flight. 2 vols.
JONES, H. C.—Introduction to Physical Chemistry.
THORPE, SIR E.—History of Chemistry. 2 vols.

Philadelphia City Directory for 1911.
Metal Statistics, 1911.
Verein zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien. Schriften, vol. 50, 1909–1910.

Gifts.

Arnold, Bion J. Report on the Pittsburgh Transportation Problem. Pittsburgh, 1911. (From Mr. Bion J. Arnold.)
Belgique Academie Royale des Sciences. Annuaire, 1911. Bruxelles, 1911. (From the Academy.)
New York Academy of Sciences. Annals, vol. 20, pts. 1 and 2. New York, 1910. (From the Academy.)
India Meteorological Office. Rainfall data for 1909. Calcutta, 1910. (From the Office.)
Association Francaise pour L'Advancement des Sciences. Compte rendu de la 38-Session, 1909. Paris, 1910. (From the Association.)
Glasgow, Royal Philosophical Society. Proceedings vol. 41, 1909–10. Glasgow, 1910. (From the Society.)
Ohio Geological Survey. Bulletin 11, Manufacture of Roofing Tiles. Columbus, 1910. (From the State Geologist.)
U. S. Navy Department. Register of the Commissioned and Warrant Officers of the United States Navy and Marine Corps, 1911. Washington, 1911. (From the Department.)
Zi-Ka-Wei Observatoire, Bulletin des Observations. Tome 33, 1907. Fascicule B., Meteorologie. Shanghai, 1910. (From the Observatory.)
Ontario Vegetable Growers' Association. Sixth Annual Report, 1910. Toronto, 1911. (From the Department of Agriculture.)
Venezuela, Ministerio de Obras Publicas Rivista Tecnica, Ano 1, Num. 2. Caracas, 1911. (From the Ministerio.)
American Mathematical Monthly, January to December, 1910. Springfield, no date. (From Mr. John McDowell.)
Interstate Commerce Commission. Twenty-fourth Annual Report for 1910. Washington, D. C., 1911. (From the Commission.)
American Gas Institute, Proceedings, vol. 5, 1910. New York, 1911. (From the Institute.)
Iowa Geological Survey. Annual Report, 1909, vol, 20. Des Moines, 1910. (From the Survey.)
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Harvard College Observatory. Annals, vols. 65 and 66. Cambridge, 1911. (From the Observatory.)

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Ontario Department of Agriculture. Annual Report 1909. Vols. 1 and 2. Toronto, 1910. (From the Department.)

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Nova Scotia Department of Mines. Report for 1910. Halifax, 1911. (From the Department.)

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India Geological Survey, Memoirs, series 15, vol. 4, fasciculus 3. Calcutta, 1910. (From the Survey.)

Pennsylvania Railroad Company, 64th Annual Report for 1910. Philadelphia, 1911. (From the Company.)

San Fernando Instituto y Observatorio de Marina. Annales, 1909. San Fernando, 1911. (From the Observatory.)

BOOK NOTICE.

COLLEGE MATHEMATICS NOTEBOOK FOR CLASSES IN ADVANCED ALGEBRA, TRIGONOMETRY, ANALYTICAL GEOMETRY AND CALCULUS. Designed and arranged by Robert E. Moritz, Ph.D., Professor of Mathematics in the University of Wisconsin. 106 loose leaves, 10½ x 8 inches, cloth cover. Price, 80 cents. Ginn & Company. Boston, 1911.

When college and university teaching is effective it is necessary for the student to adopt means for recording the subject matter of lectures, etc., for possible future use. To-day in many cases students are being provided not only with information of various kinds by means of lectures,

but they are also being supplied with the latest labor-saving devices by which a minimum of effort is required for recording on paper the information afforded by the lecturer. This notebook constitutes one of the lavor-saving devices referred to. It contains one hundred pages of co-ordinate paper including five pages in polar co-ordinates, the reverse of each sheet being ruled horizontally for other purposes. Also three pages containing important algebraic, geometric, trigonometric and other formulæ. In addition there are three pages containing seven short tables for reference and eight graphs of algebraic and other equations. The notebook cannot fail to serve the purpose apparently intended by the author.

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North Carolina Geological and Economic Survey. Bulletin No. 22. Cid mining district of Davidson County, North Carolina. By Joseph E. Pogue, Jr., Ph.D. 144 pages, illustrations, plates, maps, 8vo. Raleigh, State Printers, 1910.

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Electricity in the Development of the South, with Observations on the Importance of Federal Incorporation for Small Companies Engaged in Interstate Commerce. An address by George Westinghouse before the Southern Commercial Congress at Atlanta, Georgia, March 10, 1911. 19 pages, 8vo. Pittsburgh, Pa., the author.

Bruce-Macbeth Vertical Multicylinder Gas-engines for Electric Lighting, Pumping and General Power Purposes, Using Either Artificial, Natural or Producer Gas, or Gasoline. 31 pages, illustrations, 8vo. Cleveland, The Bruce-Macbeth Engine Co.

Les machines a écrire par Jean Rousset. Encyclopédie Scientifique des Aide-Memoire. 179 pages, illustrations, 12mo. Paris, Gauthier-Villars; no date. Price, in paper, 50 cents.

What Farmers Can Do to Assist in the Campaign Against Flies and Mosquitoes. By Wm. Paul Gerhard, C. E. 14 pages, 8vo. Brooklyn, N. Y., author, 1911. Price, in paper, 25 cents.

Canada, Mines Department, Mines Branch. Chrysotile-asbestos, its occurrence, exploitation, milling and uses. By Fritz Cirkel, M. E. Second edition, enlarged. 316 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1910.

Die Metallurgie des Zinns mit spezieller Berücksichtigung der Elektrometallurgie. Von Dr. Hans Mennicke. Monographien über angewandte Elektrochemie, xxxix Band. 196 pages, illustrations, 8vo. Halle a. S., Wilhelm Knapp, 1910. Price, in paper, 10 marks.

U. S. Census Bureau. Forest products No. 4. Tanbark and tanning extract, 1909. 14 pages, 8vo. Washington, Government, 1911. Forest products, No. 9. Poles, cross arms, brackets, and insulator pins purchased, 1909. 14 pages, 8vo. Washington, Government, 1911.

Federal Patronage. Speech of Hon. Jonathan Bourne, Jr., of Oregon, in the Senate of the United States, Monday, February 27, 1911. 16 pages, 8vo. Washington, Government, 1911.

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Journal of the American Peat Society. Devoted to the development of American peat resources. Volume 3, Nos. 3 and 4, October, 1910; January, 1911. 167 pages, portrait, 8vo. Toledo, O.; published by the Society. Price, 75 cents.

American Telephone and Telegraph Company. Annual report of the directors to the stockholders for the year ending December 31, 1910. 68 pages, illustrations, 8vo. New York, 1911.

The Temperature-Entropy Diagram. By Charles W. Berry, Assistant Professor of Mechanical Engineering in the Massachusetts Institute of Technology. Third edition, revised and enlarged. 393 pages, illustrations, 12mo. New York, John Wiley & Sons, 1911. Price, $2.50.

Elements of Descriptive Geometry, with application to spherical and isometric projections, shades and shadows, and perspective. By Albert E. Church, LL.D., late Professor of Mathematics in the United States Military Academy, and George M. Bartlett, M.A., Instructor in Descriptive Geometry and Mechanism in the University of Michigan. 286 pages, illustrations, 8vo. New York, American Book Co., n.d. Price, $2.25.

Chemistry for Beginners. I. Inorganic. By Edward Hart, Ph.D., Professor of Chemistry, Lafayette College, Easton, Pa., Ex-Fellow Johns Hopkins University. Fifth edition, revised and enlarged, with 78 illustrations and 2 plates. 214 pages, 12mo. Easton, Pa., Chemical Publishing Co., 1910. Price, $1.

U. S. Bureau of the Census. Forest products, No. 2. Lumber, lath and shingles, 1909. 63 pages, 8vo. Forest products, No. 5. Veneers, 1909. 23 pages, 8vo. Forest products, No. 6. Light cooperage stock, 1909. 14 pages, 8vo. Washington, Government Printing Office, 1911.

U. S. Senate, 61st Congress, 3rd Session. Document No. 862. Reciprocity with Canada. Mr. Carter presented this document in the consideration of bill (H. R. 32216) relating to reciprocity with Canada. 55 pages, 8vo. Washington, Government Printing Office.

National Association of Cotton Manufacturers. Advance copies of papers subject to revision. President's address, Franklin W. Hobbs. Power from producer gas, Godfrey M. S. Tait. The production of cotton in the Hawaiian Islands, E. C. Smith. Standardization of artificial illumination in cotton mills, J. S. Codman. Technical education: its function in training for the textile industry, Charles H. Eames. The laws of regain in cotton and worsted, William D. Hartshorne. Secretary's report, C. J. H. Woodbury. 7 pamphlets, 8vo. Boston, Association, 1911.

CURRENT TOPICS

Aluminum-Bronze Castings to Withstand High Pressures. H. C. H. Carpenter and C. A. Edwards. (*Eng.*, cx, 701.)—Castings capable of withstanding high pressures can be made with copper-rich aluminum-bronzes. These alloys have so small a freezing interval that no segregation takes place even when cast in sand. They are easily prepared, resist corrosion by fresh and sea water, and possess considerable tenacity and ductility, the former increasing and the latter decreasing with the increased content of aluminum. Experiments with alloys containing 9 to 11.5 per cent. of aluminum showed that simple cylinders could be cast, both in chill and sand moulds, capable of holding pressures of 15 to 20 tons per square inch. To make a more complicated casting, such as an hydraulic valve block, consisting of a lug, a barrel and a base-plate, such as is used in high-pressure pumps, it is necessary to observe the following precautions to obtain sound castings. The molten metal should remain in the crucible as long as possible before pouring, which should be done at about 1100° C. The metal should be poured very slowly and should enter the mould at the lowest possible point. It is preferable to face the mould with a somewhat coarse sand, and the surface of the lower part of the mould should be dried. Several castings have been kept for a year or two without deterioration and have been tested for a long period with high-pressure steam under service conditions, quite satisfactorily.

Hot-Blast Copper and Iron Smelting. C. H. Mace. (*Met. and Chem. Eng.*, viii, 671.)—This article is a description of the Partridge furnace, erected in the Alamos district, Sonora, Mexico. In place of the bustle pipe and tuyères, is a crucible furnace with an open space of 360° circumference,and 2.5 inches in height between the top of the crucible and the bottom of the bosh where the water-jacket ends; the crucible is on a jack-plate by which it is lifted into position beneath the bosh. The slag is not tapped but overflows by a spout, and the matte top is on the outside of the chamber. The slag is carried by small cars which travel beneath the slag top and then around the slag box and discharge automatically. The blast enters the slag box above the point where the cars discharge, passes over the molten slag and then up into the crucible chamber, reaching the smelting zone at a high temperature. This dispenses with an external stove to heat the blast, and this furnace shows that it is erroneous to introduce high-pressure blast through the tuyères. To smelt correctly the blast should enter the zone of

fusion at a speed just sufficient to maintain an active combustion; and the blast forge effect is wrong in that it causes a heavy flue dust, increases the height of the smelting zone, and volatilizes metals. The furnace described has an ore shaft 22 in. in diameter and is boshed to a diameter of 18 in., has a capacity of 25 tons per day and a minimum smelting capacity of 8.5 tons per square foot of furnace area as compared with 6.5 tons obtained by the standard smelter.

Alloys for Permanent Magnets. C. F. BURGESS AND J. ASTON. (*Met. and Chem. Eng.*, viii, 673.)—A number of bars of iron alloys, mostly free from carbon, were examined in a permeameter as to their suitability for use as permenent magnets. They were tested in the forged state and also after quenching from 1000° C. They were also tested as to their ability to retain their residual magnetism after shock. *Chromium* alone, added to iron free from carbon, does not make a material suitable for magnets, but an alloy containing 5 to 6 per cent. of chromium, with 0.75 to 1.00 per cent of silicon, or 0.3 to 0.5 per cent. of carbon, is very suitable. For every increase of *manganese* content the coercive force increased, with a corresponding decrease of retentivity, until there was 10.41 per cent. of manganese, which was non-magnetic. In the forged condition the only *molybdenum* alloy that was magnetically hard contained 8.0 per cent. of molybdenum, 0.3 of vanadium, and 0.6 of carbon; in all cases where carbon was present they became fine magnetic materials on quenching. The *nickel* alloys decreased in retentivity until 26 per cent. of nickel was reached, which was non magnetic. The addition of *vanadium* increased the magnetic hardness, which was further increased by quenching. The binary alloys of *tungsten* and iron were all unsuitable, but one with 4.0 per cent. of tungsten and 0.4 of vanadium was an exceptionally good permanent magnet. Among the ternary alloys the bad effect of nickel is particularly noted, while various combinations of chromium with molybdenum or tungsten, with or without silicon, vanadium or carbon gave satisfactory results. The decrease in residual magnetism after a series of shocks averaged 50 per cent.

Nernst's Theorem. M. PLANCK. (*Rev. Gen. des Sciences*, xxii, 92.)—The author has thrown some light upon the significance of Nernst's theorem and its importance in pure Thermodynamics. Enunciating the theorem in as simple and as general a way as possible, he reaches the conclusion that the specific heat, and the coefficient of thermal expansion, of every solid or liquid decrease indefinitely when the temperature falls.

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